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ABSTRACT

The student's manual of this set consists of materials for use by individuals enrolled in an extension course to train individuals for employment as millwrights. Addressed in the individual units of the course are the following topics: millwright careers; personal safety; equipment safety; addition and subtraction of common fractions; multiplication and division of common fractions; decimal fractions and conversion; percentage, ratio, and proportion; the metric system; blueprints; layout and measuring tools; use of various hand and power tools; gear systems; belts and pulleys; hydraulics; foundations and platforms; blocks and tackles; welding; assembly, disassembly, and maintenance of equipment; establishment of a millwright business; and human relations in business. Each unit contains objectives, instructional text, and exercises. The instructor's guide contains suggestions on how students should use the manual, and how the instructor can coordinate work experience and learning at the school. The guide also contains answers to both exercise questions and assignment test questions, one set of assignment tests, and a work sheet that can be used to match related instruction to job experience for the student. (MN)

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Millwright

Student's Manual

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By

L.A. Grimes, Jr.

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Contents

Foreword/ v

Acknowledgments/ vi

A Special Note to the Student/ vii

Section A. Introduction to Millwright

A-1: Using This Manual/1

A-2: Millwright Careers/3

A-3: Personal Safety/5

A-4: Equipment Safety/8

Section B. Basic Mathematics

B-1: Adding and Subtracting Common Fractions/11

B-2: Multiplying and Dividing Common Fractions/15

B-3: Decimal Fractions and Conversions/17

B-4: Percentage, Ratio, and Proportion/19

B-5: The Metric System/22

B-6: Reading Blueprints/25

Section C. Hand Tools

C-1: Layout and Measuring Tools/29

C-2: Handsaws/38

C-3: Files, Rasps, and Snips/41

C-4: Pounding and Driving Tools/46

C-5: Pliers and Wrenches/51

C-6: Vises and Clamps/57

C-7: Threading Tools and Reamers/61

Section D. Power Tools

D-1: Portable Electric Drills/69

D-2: Portable Electric Circular Saws/72

Section E. Fastening Devices

E-1: Bolts, Nuts, and Washers/77

E-2: Screws, Nails, and Rivets/83

Section F. Machine Elements

F-1: Gear Systems/91

F-2: Belts and Pulleys/99

F-3: Bearings and Springs/102

F-4: Hydraulics/109

F-5: Block and Tackle/114

Section G. Assembly and Disassembly

G-1: Foundations and Platforms/121

G-2: Welding/123

G-3: Assembly, Disassembly, and Maintenance of Equipment/126

Section H. Owning a Millwright Business

H-1: Setting Up a Rigging (Millwright) Business/129

H-2: Human Relations in a Business/132

COMPLIANCE STATEMENT

TITLE VI, CIVIL RIGHTS ACT OF 1964; THE MODIFIED COURT ORDER, CIVIL ACTION 5281, FEDERAL DISTRICT COURT, EASTERN DISTRICT OF TEXAS, TYLER DIVISION

Reviews of local education agencies pertaining to compliance with Title VI Civil Rights Act of 1964 and with specific requirements of the Modified Court Order, Civil Action No. 5281, Federal District Court, Eastern District of Texas, Tyler Division are conducted periodically by staff representatives of the Texas Education Agency. These reviews cover at least the following policies and practices:

- (1) acceptance policies on student transfers from other school districts;
- (2) operation of school bus routes or runs on a non-segregated basis;
- (3) nondiscrimination in extracurricular activities and the use of school facilities;
- (4) nondiscriminatory practices in the hiring, assigning, promoting, paying, demoting, reassigning, or dismissing of faculty and staff members who work with children;
- (5) enrollment and assignment of students without discrimination on the basis of race, color, or national origin;
- (6) nondiscriminatory practices relating to the use of a student's first language; and
- (7) evidence of published procedures for hearing complaints and grievances.

In addition to conducting reviews, the Texas Education Agency staff representatives check complaints of discrimination made by a citizen or citizens residing in a school district where it is alleged discriminatory practices have occurred or are occurring.

Where a violation of Title VI of the Civil Rights Act is found, the findings are reported to the Office for Civil Rights, Department of Health, Education and Welfare.

If there is a direct violation of the Court Order in Civil Action No. 5281 that cannot be cleared through negotiation, the sanctions required by the Court Order are applied.

TITLE VII, CIVIL RIGHTS ACT OF 1964; EXECUTIVE ORDERS 11246 and 11375; TITLE IX 1973 EDUCATION AMENDMENTS; REHABILITATION ACT OF 1973 AS AMENDED; 1974 AMENDMENTS TO THE WAGE-HOUR LAW EXPANDING THE AGE DISCRIMINATION IN EMPLOYMENT ACT OF 1967; VIETNAM ERA VETERANS READJUSTMENT ASSISTANCE ACT OF 1972 AS AMENDED IN 1974.

It is the policy of the Texas Education Agency to comply fully with the nondiscrimination provisions of all federal and state laws and regulation by assuring that no person shall be excluded from consideration for recruitment, selection, appointment, training, promotion, retention, or any other personnel action, or be denied any benefits or participation in any programs of activities which it operates on the grounds of race, religion, color, national origin, sex, handicap, age, or veteran status (except where age, sex, or handicap constitute a bona fide occupational qualification necessary to proper and efficient administration). The Texas Education Agency makes positive efforts to employ and advance in employment all protected groups.

Foreword

This publication is one of a series of individualized instructional materials for trade and industrial students. Students using this material can work at their own pace, learning those things that best fit specific needs. The design of the material makes it possible to relate work experience on the job with information studied at school.

Although the material is designed for individualized study, it should be used under the supervision of an instructor. For that reason, two basic publications are offered—a student's manual and an instructor's guide.

The **student's manual** is for the person in training. It is self-contained. Each assignment has all the information needed, a list of objectives that should be met, and exercise questions that can help in meeting those objectives.

The **instructor's guide** has additional information that may help the instructor help the student. There are suggestions on how the student should use the student's manual, and how the instructor can coordinate work experience and learning at school. The instructor's guide also contains (1) answers to the exercise questions and assignment test questions, (2) one set of assignment tests, and (3) a work sheet that the instructor can conveniently use to match related instruction to job experience for the student.

Although both publications are copyrighted, an instructor should feel free to make copies of the assignment tests and work sheet, which have been placed in a separate section of the instructor's guide. If the instructor prefers, copies of these same sheets can be ordered for individual students from Extension Instruction and Materials Center, The University of Texas at Austin, P.O. Box 7218, Austin, Texas 78713.

Every effort has been made to produce a publication that addresses the unique needs of our current student population. Students with limited English proficiency (LEP) as well as handicapped, educationally disadvantaged, and nontraditional students may require modification of the material in this publication. The professional staff of EIMC will gladly work with any instructor having these students to show how the instructional material can be adapted for specific individualized instruction. Consult local, state, and federal agencies that offer assistance and guidance and that can provide sound recommendations for productive classroom management.

Kathryn R. Allen, Ph.D.
Director, Extension Instruction and
Materials Center

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A Special Note to the Student

The assignments in this manual are designed to help you learn. You will gain more from the material if you know how to work the assignments. For that reason, Assignment A-1, which is about how to use this manual, should be completed first.

A-1

Using This Manual

Objectives: After completing this assignment, you will be able to—

1. state the purpose of a student's manual;
 2. discuss the reasons for the assignment objectives;
 3. discuss the procedure to use when studying the information part of an assignment;
 4. discuss the uses of the assignment exercises; and
 5. tell how the assignment tests are used.
-

Purpose of Student's Manual

A student's manual is designed to present technical instructions, procedures, and illustrations to groups of trade and industrial students. It may also be used by other groups in which the learning levels of individual students vary considerably. It is not intended to be used as a correspondence course, but must be used by students under the direct supervision of an instructor.

Information in the student's manual is designed to be read at about the same time that related operations are being done on the job. For example, while the student is learning about using hoists on the job, he or she should be reading in the student's manual about types of hoists and how they are used. This combination of classroom study and the actual work on the job gives the student well-rounded knowledge and experience in each specific operation.

Parts of an Assignment

Objectives. In order for the student to know what he or she should learn, each assignment begins with a list of objectives. The student should study the objectives before reading the information part of the assignment. After finishing the assignment, the

student should reread the objectives to see if he or she has succeeded in meeting them. Success is checked through the use of the exercise and test.

Information. All the information for each assignment is given in the assignment itself. The exercise and assignment test for each assignment are based on the information in that assignment. The student should read all the information carefully before answering the exercise questions. Any illustrations should also be studied. Tools and materials may be shown, as well as certain procedures and operations. The student should reread any information that is unclear when answering the exercise questions. Certain tasks on the job may also make it necessary to refer back to the assignment information.

Exercise. The exercise questions are based on the information given in the assignment and are designed to help the student meet the objectives. The student should write both the question and the answer on separate sheets of paper. The answer should be in the form of a complete sentence. After the instructor has checked the exercise questions, the student should correct any mistakes and place the papers in his or her notebook. If the exercise questions have been answered correctly, the

objectives stated at the beginning of the assignment have been met. The exercise questions in this manual are designed to make the student think. The student should consider each question carefully before writing an answer.

Tests. The assignment test is a short quiz of about five questions that may be answered very quickly. A test may be given as soon as the specific assignment has been completed, or several tests may be combined and given together as a weekly or six-weeks' test. The assignment test questions are either fill-in-the-blank or multiple-choice questions.

Exercise

1. What is a student's manual designed to present to the student?
2. What combination gives the student well-rounded knowledge and experience about each specific operation?
3. Name the four parts of an assignment.
4. When should the assignment objectives be studied?
5. What should the student do before trying to answer the exercise questions?
6. What may be shown in the illustrations?
7. When is it sometimes necessary to re-read information in the assignment?
8. What is the purpose of the exercise questions?
9. In what form should the answers to exercise questions be written?
10. What should the student do with the exercise questions as soon as they have been checked by the instructor?
11. When may it be assumed that the assignment objectives have been met?
12. What are the exercise questions in this student's manual designed to do?
13. When may assignment tests be given?
14. What types of questions are found in the assignment tests?

A-2

Millwright Careers

Objectives: After completing this assignment, you will be able to—

1. discuss the various types of jobs with which millwrights are involved;
 2. discuss the qualifications and training needed by millwrights;
 3. describe earnings and working conditions of millwrights; and
 4. give the employment outlook for millwrights in the 1980s.
-

Job Opportunities

Millwrights are responsible for a great number of duties that require the knowledge and experience of several other trades. The field is closely related to that of building mechanic, but requires more responsibility.

Millwrights install machinery and equipment according to layout plans, drawings, and blueprints. Duties include the erection and construction of foundations or bases for heavy equipment or for smaller units, such as motors or kilns. Millwrights must know mixtures and strengths of wood, steel, and concrete.

Millwrights install and align equipment using hoists, cranes, jacks, squares, micrometers, levels, plumb bobs, and transits. Equipment is fastened and secured using screws, bolts, rivets, and welding equipment. Equipment is assembled and disassembled with such hand tools as hammers, screwdrivers, wrenches, and crowbars. Portable electric tools, such as drills and circular saws, are also used.

Millwrights are responsible for repairing and rebuilding pulleys, belting, conveyors, cranes, elevators, and furnaces. They must sometimes move machinery to new

locations and erect or assemble the unit. Millwrights are sometimes responsible for operating an engine lathe to grind, file, and turn machine parts to dimensional specifications. Milling machines, bench and die grinders, and drill presses are also used. Sometimes special tools and jigs must be constructed for specific jobs.

Millwrights are often required to inspect and maintain machinery and equipment by lubricating and repairing it. They may assist in making and installing machine guards for some equipment and replacing drive gears and flywheels. They may set up electrical equipment, but the wiring is done by electricians.

Places of Employment

There are about 95,000 millwrights in the United States. They are employed mainly by manufacturing companies in transportation equipment, metal, paper, lumber, and chemical products industries. Some work for contractors in the construction industry. Millwrights are more highly concentrated in the north and northeastern states, although the demand is increasing in the southern states.

Training Necessary

Some millwrights begin working as helpers to skilled millwrights and learn the skills needed without formal apprenticeship. This method usually takes the person 6 to 8 years to become a skilled millwright.

Formal apprenticeship programs combine on-the-job training with classroom instruction and usually take 4 years. The training program includes dismantling, moving, erecting, and repairing machinery. Other instruction includes mathematics, blueprint reading, hydraulics, carpentry, welding, and sheet metal work. Safety is also stressed. Applicants must be at least 17 years old, and some employers prefer high school or vocational school graduates. High school courses that are helpful include mathematics, mechanical drawing, and machine shop. Mechanical aptitude is very important, and often strength is a factor in handling heavy equipment.

Employment Outlook

The demand for millwrights is expected to increase about as fast as the average for all other occupations through the 1980s. The demand will increase as new plants are built, old plants updated, and new types of equipment become available. Many openings will arise as experienced millwrights retire, die, or transfer to other occupations.

Earnings and Working Conditions

Base hourly wages for journeymen millwrights average about \$14.81, with an extra \$2.18 per hour in benefits. This is consider-

ably higher than the average wage for most other workers in private industry.

Most millwrights work year-round, unless they are employed by companies that only manufacture and install machinery. These companies usually pay higher wages, but travel may be required.

Millwrights are subject to cuts and bruises, injury from falling objects, falls, and strains from lifting heavy equipment. Protective equipment has helped to reduce many injuries.

Exercise

1. How do millwrights know where and how to install machinery and equipment?
2. What power tool may be used to grind, file, and turn machine parts to dimensional specifications?
3. How is equipment fastened and secured?
4. How many millwrights are there in the United States?
5. What types of manufacturers employ most millwrights?
6. How long is the apprenticeship program for millwrights?
7. What high school courses are helpful for a person planning a career as a millwright?
8. What is the expected employment outlook for millwrights in the 1980s?
9. What is the average base hourly wage for journeymen millwrights?
10. What physical dangers are millwrights subject to?
11. What has helped to reduce many injuries to millwrights?

A-3

Personal Safety

Objectives: After completing this assignment, you will be able to—

1. give general requirements for good housekeeping around an assembly or disassembly job;
 2. discuss personal protective devices that should be worn;
 3. discuss ladder safety; and
 4. give the steps to use when lifting heavy weights.
-

Good Housekeeping

Good housekeeping on a job means the orderly placement and storage of tools and materials. Housekeeping rules also serve as safety measures because loose articles and litter may cause you or another worker to stumble or fall, resulting in an injury. Poor housekeeping often creates fire hazards and slows fire-fighting efforts. Common sense can prevent accidents as well as damage to materials and equipment.

Always keep the work space clear and safe for all persons in the area. Place tools and materials where they cannot fall and where no one is likely to stumble over them. When material must be piled, make the pile neat and compact. Never lean tools or materials against a wall or other support that might collapse under the additional weight or where they could be jarred loose.

The floor should always be kept dry, and spills cleaned up promptly. Areas that are constantly wet should have nonslip surfaces where people usually walk or work.

Place all flammable materials (including greasy waste, oil-soaked rags, or paint-covered cloths) in an approved waste can for proper disposal. Do not use gasoline as a cleaning agent. It is better to use a low-hazard solvent. Keep flammable liquids in

safety cans equipped with self-closing covers.

Ladders

Many assembly or disassembly operations require the use of ladders. Precautions should be taken to prevent falls.

Ladders are either fixed or portable. **Portable** ladders are the single-unit, step-ladder, or extension type. Most ladders are made of metal or wood, although some very expensive ones are made of fiberglass.

Fixed ladders should be able to withstand a single concentrated load of at least 200 pounds. The rungs should be at least 3/4 inch in diameter for metal ladders and 1 1/8 inches for wood ladders. The rungs should be no more than 12 inches apart and at least 16 inches wide. The climbing side should have a clearance of 2 1/2 feet for ladders with a 90° pitch and 3 feet for those with a 75° pitch.

Portable ladders should be kept in good condition at all times and coated with a suitable protective material. Wood ladders should have a transparent coating so that you can see any cracks or flaws that might develop.

All ladders should be inspected often. Wood ladders should be stored where they

will not be exposed to the weather, and where there is good ventilation. Do not use metal ladders near energized electrical equipment. Never place portable ladders on boxes, barrels, or other unstable bases for more height.

When setting up long, straight, or extension ladders, brace the lower end of the ladder against something solid so that it cannot slide. Place the ladder at the correct angle to the wall. The base of the ladder should be one-fourth of its working length away from the wall or support. If the ladder is placed at too great an angle (with the base too far out), the stress can cause it to break or slip. If the base is too close to the wall, the ladder may tip backwards. Be sure the ladder has a firm footing before you climb it.

Never climb higher than the step below the top of a stepladder. If you stand on the top, you may lose your balance. Go up and down a ladder carefully, always facing the ladder. Carry tools or other work materials in your clothing or attached to a belt. Never overreach or lean to the side of the ladder.

Personal Protective Devices

Noise Exposure. Excessive noise is a common problem for those working around power equipment. It can cause permanent hearing damage. Be sure you are not exposed to noise levels greater than the standards set by the National Institute for Occupational Safety and Health (NIOSH). If you work around high noise levels, you should have your hearing checked regularly. Several types of protective devices may be used, from earmuffs to earplugs. Some are better than others, depending on the type of noise, the frequency of the noise, and how well the device fits the individual.

Fumes and Dusts. You may be required to work in areas where fumes or dusts are present, or you may be using materials and solvents that could be dangerous if inhaled. Be sure to wear an approved respirator under these conditions.

Eye Protection. Eye protection is needed where there is a possibility of an eye injury from flying particles, chips, caustic materials, and solvent splashes. You should also wear eye protective devices when using lathes, grinders, drills, welders, and other power equipment.

Protective Clothing. Wear gloves when handling hazardous liquids, resins, or heated materials. They should also be worn when handling sheets of metal or splintery wood. Hard hats are needed where you might be hit by falling or flying objects. Steel-toed shoes help prevent injury from falling objects. Rubber soles may be necessary when working around electricity.

Lifting Heavy Objects by Hand

Since lifting heavy items is often necessary in your work, the following suggestions are given to help prevent serious strains and injuries. Figure 1 shows the proper lifting position.

1. Check the load before beginning to lift. Get help if necessary.
2. In general, lift loads no heavier than 35 percent of your body weight.
3. Lift with the hands and legs, and not the back.
4. Keep your feet close to the object being lifted, with one foot slightly closer than the other for better balance.
5. Use a narrow stance, with your feet about 8 to 12 inches apart.
6. Do not lift an excessively heavy load. To make a heavy lift, first assume a squatting position with the back erect, then raise the object by straightening the legs. This easy and safe method will bring the leg muscles into use and take the strain off the back.
7. When two or more workers are working together, lifting and lowering must be done at a prearranged signal in order to equalize the load. The entire body should always be pushed upward with the legs.

Exercise

1. Why should you never lean tools or materials against a wall or other support?
2. How should the floor always be kept if possible?
3. What should you never use as a cleaning agent?
4. Name the three types of portable ladders.

5. What kind of coating should wood ladders have?
6. When should metal ladders not be used?
7. How far should the base of a long, straight, or extension ladder be from the wall it is leaning against?
8. Why should you never climb higher than the step below the top of a stepladder?

9. What can you use to protect your head from falling objects?
10. What position should you assume to make a heavy lift?
11. What organization sets safe noise level standards?
12. When is eye protection needed?



Fig. 1. Lift correctly.

A-4

Equipment Safety

Objectives: After completing this assignment, you will be able to—

1. give general hand tool safety precautions;
 2. discuss safety rules to follow when using portable electric tools; and
 3. give the safety rules to follow when using drill presses, grinders, metal lathes, and welders.
-

General Hand Tool Safety

Although hand tools do not usually cause severe injuries, most industrial accidents occur during their use. Keep in mind that all cutting tools should be kept sharp. Forcing a dull cutting tool often causes accidents. Sharp hand tools should not be carried on the person unless they are in a sheath or tool belt. Do not place hand tools on surfaces where they could be bumped or knocked off. Be sure that all handles are secure and that hammer and mallet faces are flat so they will not slip off a hammering surface when a blow is struck. See that chisels do not have mushroomed heads.

General Rules for Power Equipment

Never leave hand tools or scraps on a machine or on the floor near the machine. Tools or scraps on the machine may vibrate into moving parts. Materials on the floor may cause a person to lose his/her balance and fall into a moving part. **Never** engage in any type of horseplay around the equipment.

Make all adjustments before a machine is turned on. Never leave unattended a machine that is still running. Do not engage in conversation while operating power equipment, as you cannot give full attention to the equipment during that time.

Loose sleeves, aprons, or other loose wearing apparel can be very dangerous around any revolving equipment. Long hair should be netted or placed under a cap. Jewelry can also be dangerous—especially around electrical switches and equipment. Most machines have from one to several guards. Use them; they are there to protect you.

Portable Electric Drill Safety

Although the portable drill is not as dangerous as other power equipment, certain rules should be observed. Never force a drill into the work, as this may break a drill bit. Be sure the bit is cool before touching it. Many burns result from attempting to change a bit while it is still very hot. Never hold a hand beneath the material where you are drilling. Also, be sure that another worker is not behind any material where you are drilling. Be sure the drill is grounded to avoid electrical shock.

Portable Electric Circular Saw Safety

A portable circular saw has an exposed saw blade during the cutting operation. Do not allow your hands to be near this blade. Never reach below the material while the saw is in the cut. It is easy to forget that

the exposed blade is turning beneath the wood. Be sure that the under guard is working correctly so that it covers the blade as soon as the cut has been made. Hold the saw straight to avoid kickback.

Drill Press

Sometimes a millwright will use a drill press to drill holes in metal or wood. Again, remember that the drill is hot immediately after a hole has been drilled. Use goggles to prevent wood and metal chips from being thrown into the eyes. Clamp the material to the table to keep the bit (especially large bits) from "grabbing" the material and spinning it. Fingers and hands can be severely injured when they are in the way of the spinning material. See that guards are in place, and never leave a key in the chuck.

Grinder Safety

Use a shatterproof face shield or goggles for all grinding operations. Be sure the tool rest is close to the stone to prevent the piece being ground from slipping between them. Stand to one side when using the grinder. Severe injury and many deaths have occurred from blown-up stones. If the stone is faulty, it usually breaks when the grinder is first started. Always grind on the face of the wheel.

Metal Lathe Safety

You will sometimes need to turn parts on a metal lathe. Always wear goggles or shields to protect the eyes. Remember that the head of the lathe and the work you are turning are capable of catching anything loose and wrapping it around the material. Do not wear rings or other jewelry when operating this equipment. Also, you must check that all parts are tight so that machine parts or working materials are not thrown from the machine. Never walk away from the machine when it is turning, as

another worker may not be aware that it is turning.

Welders

The two primary types of accidents around welders are eye damage from not wearing protective goggles or a welding hood and burns from sparks or handling hot metals. Be sure the goggles or hood shields your eyes from the intense light of the torch or arc. Boots or high-topped shoes should be worn so that sparks cannot fall into your shoes. Wear protective gloves, and do not handle hot metals. At times the fumes from certain metals can also cause respiratory problems. Wear respirators when doing this type of work.

Arc welders also can cause severe ultraviolet burns (sunburn). Wear long sleeves and/or leathers. Sustaining an electrical shock is also a hazard.

Exercise

1. Why should all cutting tools be kept sharp?
2. Why should hammer and mallet faces be kept flat?
3. Why should materials be removed from the floor near a machine?
4. Why should materials be clamped to a drill press table?
5. Why should a tool rest be close to a grinder stone?
6. When does a grinding stone usually break?
7. What should be worn for all grinding operations?
8. Why should you check to see that all parts of a metal lathe are tight before turning on the machine?
9. What kind of apparel can be dangerous around revolving equipment?
10. How might you be burned when using a portable drill?
11. Why should you hold a portable circular saw straight when making a cut?
12. What are the two primary types of accidents around welders?

B-1

Adding and Subtracting Common Fractions

Objectives: After completing this assignment, you will be able to—

1. discuss the meaning of fractions;
2. work problems adding common fractions; and
3. work problems subtracting common fractions.

Definitions and Terms

A **fraction** is a part of a whole. Since the millwright works with scales that show measurements in parts of inches and feet, it is important to know how to figure in inches and fractions of an inch.

If a whole object is cut into 2 parts, each part equals $\frac{1}{2}$ of the whole, or 1 of 2 parts. If the object is cut into 4 parts, each part equals $\frac{1}{4}$ of the whole, or 1 of 4 parts. Figure 1 shows two examples of shapes that have been cut into a number of smaller parts—or fractional parts—of the whole object.

The millwright sometimes uses rules for measuring. The 12-inch rule is divided into 12 equal parts or inches. This means that each inch is equal to $\frac{1}{12}$ of the total length of the rule, or 1 part of the whole 12 inches. Figure 2 shows how one part of the rule is equal to a number of smaller parts. On the shaded part of the rule, $\frac{1}{3}$ of the rule is the same as $\frac{2}{6}$ of the rule or $\frac{4}{12}$ of the rule.

Each of the two numbers in a fraction is identified by a name. The number above the line is the **numerator**. The number below the line is the **denominator**.

$$\frac{1 \text{ (numerator)}}{8 \text{ (denominator)}}$$

One of the basic operations you will perform with fractions is called **reducing to**

lowest terms. Suppose you have these fractions:

$$\frac{1}{2} \quad \frac{2}{8} \quad \frac{4}{16}$$

The operation used to reduce these fractions to their lowest terms is called **cancellation**. In cancellation, the largest possible number (other than 1) that will go evenly is divided into both the numerator and denominator of the fraction. The fraction $\frac{1}{2}$ is already reduced to its lowest terms. It cannot be divided evenly by any number other than 1. The largest number that can be divided evenly into the fraction $\frac{2}{8}$ is 2. The largest number that will go into $\frac{4}{16}$ evenly is 4. These fractions are now reduced to their lowest terms by cancelling out the numbers you are reducing and writing in the new numbers as you divide:

$$\frac{1}{2} \quad \frac{\cancel{2}}{\cancel{8}_4} \quad \frac{\cancel{4}}{\cancel{16}_4}$$

Just as apples and oranges cannot be added or subtracted together, fractions with different denominators cannot be added or subtracted together. Suppose, after reducing them to their lowest terms, you want to add together:

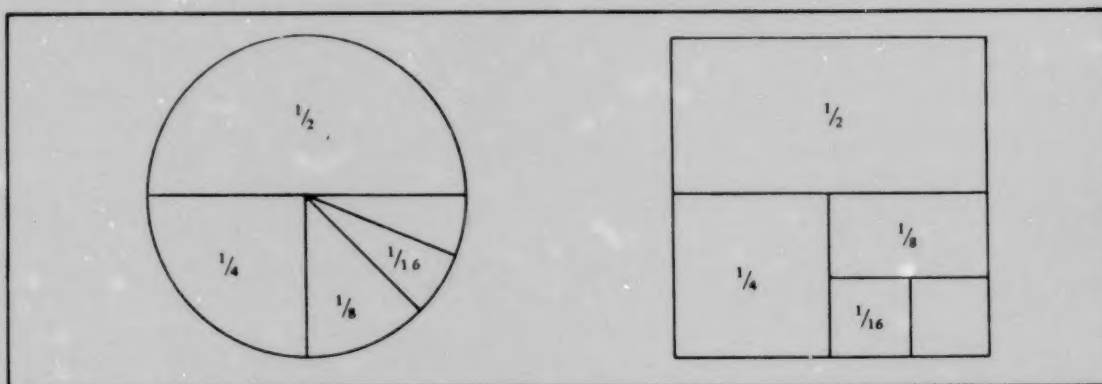


Fig. 1. Fraction examples

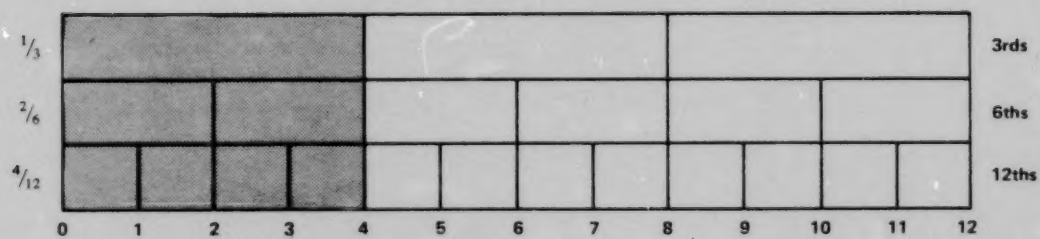


Fig. 2. Dividing lengths into fractions

$$\frac{1}{2} + \frac{1}{4} + \frac{1}{4}$$

To add or subtract fractions with different denominators, you must first perform an operation that makes all the denominators the same without changing the value of the fraction. This is called **finding the lowest common denominator**. The lowest common denominator is the lowest number into which the denominator of each of the fractions you want to add or subtract will divide evenly.

In the case of $\frac{1}{2}$, $\frac{1}{4}$, and $\frac{1}{4}$, the lowest number all three denominators will divide into is 4. The fractions $\frac{1}{4}$ and $\frac{1}{4}$ already have that denominator. When you change the denominator of $\frac{1}{2}$ into 4, to avoid changing the value of the fraction, you must also change the numerator. To get the new numerator, divide the old denominator into the lowest common denominator and multiply the old numerator by the number you get. In this case, the result is $\frac{2}{4}$. The fraction $\frac{2}{4}$ has the same value as $\frac{1}{2}$, but it can be added or subtracted with other fractions with a lowest common denominator of 4.

Sometimes the lowest common denominator is not as obvious as it was above. Say you want to add:

$$\frac{1}{4} + \frac{1}{3}$$

A common denominator is found in this example by multiplying the two denominators (3 and 4) together. The common denominator is 12. Both fractions are then changed to twelfths. To get the new numerator when you change $\frac{1}{4}$ into twelfths, follow the same procedure you did above. Divide 4 into 12 and multiply by the numerator, 1, which gives you $\frac{3}{12}$. To get the new numerator when you change $\frac{1}{3}$ into twelfths, divide 3 into 12 and multiply the numerator, 1, to give you $\frac{4}{12}$. Now that they have a common denominator, 12, these two fractions can be added (or subtracted) together.

A fraction with a denominator larger than the numerator is a **proper fraction**. The fraction $\frac{1}{3}$ is an example of a proper fraction. If the fraction has a numerator that is larger than the denominator, it is an **improper fraction**. The fraction $\frac{3}{2}$ is an example of an improper fraction.

Mixed numbers contain both a whole number and a proper fraction. The number $2\frac{1}{4}$ is an example of a mixed number. When changing a mixed number to an improper fraction, multiply the whole number by the denominator of the fraction and add the numerator of the fraction. For instance, to change $2\frac{1}{4}$ to an improper fraction, multiply 2 by 4 and add 1. The improper fraction is $\frac{9}{4}$. To change an improper fraction to a mixed number, divide the numerator by the denominator. To change the improper fraction $\frac{5}{2}$, 2 is divided into 5. The mixed number is then $2\frac{1}{2}$.

Adding Common Fractions

To add common fractions:

1. Find the lowest common denominator, if necessary.
2. **Add the numerators.**
3. Write the sum of the numerators over the common denominator.
4. Reduce the fraction to its lowest terms, if necessary.

In the example below, the denominators are the same, so finding the lowest common denominator is not necessary.

$$\frac{1}{8} + \frac{3}{8} = \frac{4}{8} \text{ (add numerators and write over denominator)}$$

$$\frac{4}{8} = \frac{1}{2} \text{ (reduce to lowest terms)}$$

When the denominators are different, the common denominator must be found. Say you want to add:

$$\frac{1}{4} + \frac{1}{8}$$

The lowest common denominator is 8. The fraction $\frac{1}{4}$ is changed into eighths by dividing 4 into 8 and multiplying the answer, 2, by the numerator. The resulting fraction is $\frac{2}{8}$.

$$\frac{2}{8} + \frac{1}{8} = \frac{3}{8}$$

Sometimes more than two fractions are added together. For example, the problem is:

$$\frac{1}{2} + \frac{1}{3} + \frac{1}{5}$$

The denominators 2 and 3 will not divide into 5. In this case, all three denominators

must be multiplied together to find a common denominator. Thus, $2 \times 3 \times 5 = 30$; the common denominator is 30. Change each fraction to this denominator. Then the problem is:

$$15/30 + 10/30 + 6/30 = 31/30$$

When you change this fraction to a mixed number, the answer is $1 \frac{1}{30}$.

Mixed numbers are added as shown in the three examples below.

$$\begin{array}{r} 1 \frac{3}{4} \\ + 3 \frac{1}{4} \\ \hline 4 \frac{4}{4} \text{ or } 5 \end{array} \quad \begin{array}{r} 4 \frac{3}{8} \\ + 5 \frac{1}{2} (4/8) \\ \hline 9 \frac{7}{8} \end{array} \quad \begin{array}{r} 1 \frac{1}{8} \\ 2 \frac{1}{4} (2/8) \\ + 4 \frac{1}{2} (4/8) \\ \hline 7 \frac{7}{8} \end{array}$$

Subtracting Common Fractions

To subtract fractions that have the same denominator, follow the same procedure as for addition except that one numerator is subtracted from the other. For example, $1/8$ subtracted from $3/8$ equals $2/8$, which can be reduced to $1/4$. When the denominators are different, find the lowest common denominator as when adding fractions. The problem is to subtract $3/16$ from $1/4$. The 16 is used as the common denominator. The fraction $1/4$ is then changed to $4/16$. When $3/16$ is subtracted from $4/16$, the answer is $1/16$.

Mixed numbers are worked similarly, except when subtracting a larger fraction from a smaller one. When this happens, a whole number is borrowed and added to the smaller fraction. For instance, if $1 \frac{3}{8}$ is subtracted from $2 \frac{1}{8}$, a whole number is borrowed from 2. The whole number is

equal to $8/8$, so $8/8$ is added to $1/8$. The problem then reads $1 \frac{3}{8}$ subtracted from $1 \frac{9}{8}$. The answer is $6/8$, which is reduced to $3/4$.

Exercise

1. Define the word **fraction**.
2. If an object is divided into four parts, how is the fraction for one part written?
3. How many sixths does the fraction $1/3$ contain?
4. What is the number above the horizontal line in a fraction called?
5. What is the number below the horizontal line in a fraction called?
6. What is it called when all denominators are made the same without changing the value of the fraction?
7. What type of fraction has a numerator that is larger than the denominator?
8. What are mixed numbers?
9. What is a common denominator?
10. What must be done when subtracting mixed numbers and a larger fraction must be subtracted from a smaller one?
11. Work the following problems in addition of fractions.
 - a. $1/4 + 1/6$
 - b. $1/3 + 4/7$
 - c. $3/8 + 1/2$
 - d. $2/5 + 1/7$
 - e. $1/9 + 1/6$
12. Work the following problems in subtraction of fractions.
 - a. $2/4 - 1/8$
 - b. $7/8 - 2/5$
 - c. $3/4 - 1/3$
 - d. $2/9 - 3/18$
 - e. $5/7 - 2/9$

B-2

Multiplying and Dividing Common Fractions

Objectives: After completing this assignment, you will be able to—

1. define terms and give rules used in multiplying fractions;
2. define terms and give rules used in dividing fractions;
3. work problems multiplying common fractions; and
4. work problems dividing common fractions.

Definitions of Multiplication Terms

Confusion may arise if the terms used are not clear to the person working a problem. The **multiplicand** is the number to be multiplied by another number. The **multiplier** is a number which multiplies the multiplicand. The **product** is the answer you get when the two numbers are multiplied together.

Multiplying Fractions

Four different basic operations for multiplying fractions are common. The first three of the operations are used more often by the millwright and should be learned. (1) Two fractions ($1/4 \times 1/8$) may be multiplied together. (2) A fraction and a whole number ($1/2 \times 8$) may be multiplied. (3) A mixed number and a whole number ($3\ 1/2 \times 4$) may be multiplied. (4) Two mixed numbers ($3\ 1/9 \times 2\ 1/4$) are seldom multiplied by the millwright. There are different rules for each operation.

To multiply a fraction by a fraction, multiply the numerator of one fraction by the numerator of the other to get the numerator of the product. The denominators are multiplied together to get the denominator of the product. For example,

$$1/4 \times 1/8 = \frac{1 \times 1}{4 \times 8} = 1/32$$

To multiply a fraction by a whole number, multiply the numerator of the fraction by the whole number, then divide the result by the denominator. For example,

$$5 \times 3/4 = \frac{5 \times 3}{4} = 15/4 = 3\ 3/4$$

Notice that in this particular problem the product was an improper fraction. The denominator 4 was then divided into the numerator 15. This gives an adjusted product of 3 whole numbers and $3/4$ of a whole number, or $3\ 3/4$.

Sometimes the **cancellation** operation is used in problems of this type. This operation is used to simplify the problem when a common number can be divided evenly into both the numerator and denominator. The example below shows cancellation.

$$4/8 \times 16 = \frac{4 \times \overset{2}{\cancel{16}}}{\underset{1}{\cancel{8}}} = 8/1 = 8$$

The number 8 is used as a common number and is divided into both 16 and 8. The numerators are multiplied, giving a numerator of 8 and denominator of 1. The fraction $8/1$ equals 8.

To multiply a mixed number by a whole number, the fractional part of the mixed

number is multiplied by the whole number. The whole numbers are then multiplied and the two products added, as in the example below.

$$2 \frac{1}{2} \times 4 \qquad \frac{1}{2} \times 4 = \frac{4}{2} = 2$$

$$2 \times 4 = \frac{8}{1}$$

Another way to multiply these numbers is shown in the example below.

$$2 \frac{1}{2} \times 4 = \frac{5}{2} \times 4 = \frac{5 \times 4}{2 \times 1} = \frac{20}{2} = 10$$

Definitions of Division Terms

In division, the **dividend** is the number that is divided. The **divisor** is the number that divides into the dividend. The **quotient** is the number that results from the division of one number by another.

Dividing Fractions

Five different operations are possible in dividing fractions. (1) A fraction is divided by a whole number or (2) by another fraction. (3) A mixed number is divided by a whole number or (4) by another mixed number. (5) A whole number is divided by a fraction. Each operation requires a different rule. The millwright normally performs the first three operations.

To divide a fraction by a whole number, multiply the denominator of the fraction by the whole number. For example,

$$\frac{3}{4} \div 2 = \frac{3}{4 \times 2} = \frac{3}{8}$$

In figure 1, the length is divided into four parts ($\frac{4}{4}$). The problem says to divide $\frac{3}{4}$

by 2 or to divide $\frac{3}{4}$ of a whole into 2 parts. Figure 1 shows that each half of $\frac{3}{4}$ equals $\frac{3}{8}$.

To divide a fraction by another fraction, invert the divisor fraction and work the problem as in multiplying a fraction by a fraction. To invert a fraction means to turn it upside down. The fraction $\frac{1}{2}$ inverted is $\frac{2}{1}$.

$$\frac{1}{4} \div \frac{1}{2} = \frac{1}{4} \times \frac{2}{1} = \frac{1 \times 2}{4 \times 1} = \frac{2}{4} = \frac{1}{2}$$

To divide a mixed number by a whole number, change the mixed number to an improper fraction and then divide as shown in the example below.

$$3 \frac{1}{4} \div 4 = \frac{13}{4} \div 4 = \frac{13}{4 \times 4} = \frac{13}{16}$$

Exercise

1. Define the term **multiplicand**.
2. Define the term **multiplier**.
3. What is the rule for multiplying a fraction times a whole number?
4. What is the rule for multiplying a fraction by a fraction?
5. Define the term **divisor**.
6. What is the rule for dividing a fraction by a whole number?
7. What does inverting a fraction mean?
8. Work the following problems in multiplication of fractions.
 - a. $\frac{3}{4} \times \frac{6}{7}$
 - b. $\frac{1}{10} \times \frac{3}{4}$
 - c. $\frac{8}{9} \times 3$
 - d. $\frac{1}{6} \times \frac{3}{5}$
9. Work the following problems in division of fractions.
 - a. $\frac{1}{4} \div \frac{1}{8}$
 - b. $\frac{1}{3} \div \frac{1}{6}$
 - c. $5 \frac{1}{2} \div 6$
 - d. $2 \frac{2}{3} \div 3$

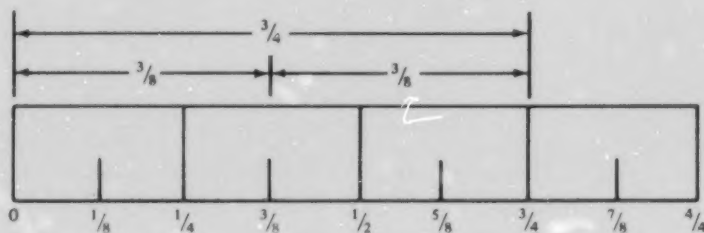


Fig. 1. Dividing $\frac{3}{4}$ into two parts

B-3

Decimal Fractions and Conversions

Objectives: After completing this assignment, you will be able to—

1. add and subtract decimal fractions;
2. multiply and divide decimal fractions;
3. convert fractions to decimals; and
4. convert decimals to fractions.

Decimal Fractions

In the metric system, fractional quantities are always expressed as decimal fractions. Decimals are fractional quantities in which the denominator is ten or a multiple of ten and the denominator is understood rather than expressed.

A simple rule for determining the number of zeros in the denominator is to remember that there are the same number of zeros in the denominator as there are figures to the right of the decimal point in the fraction. For example,

0.1 is read one-tenth (1/10).

0.02 is read two-hundredths (2/100).

0.003 is read three-thousandths (3/1,000).

0.0004 is read four ten-thousandths (4/10,000).

.00005 is read five hundred-thousandths (5/100,000).

.000006 is read six-millionths (6/1,000,000).

1.1 is read one and one-tenth (1 1/10).

Addition. The addition of decimal fractions is basically the same as for other quantities. It is necessary only to write the quantities down in such a way that the decimal points come under one another and then proceed as in simple addition. The examples below show both simple and more difficult forms of adding decimal fractions.

$$\begin{array}{r} 0.03 \\ + 0.21 \\ \hline 0.24 \end{array} \qquad \begin{array}{r} 10.3 \\ + 9.7 \\ \hline 20.0 \end{array} \qquad \begin{array}{r} 3.04 \\ 0.005 \\ + 8.014 \\ \hline 11.059 \end{array}$$

Subtraction. Subtracting decimal fractions is done in the same way as adding them. Be sure that the decimal points line up. Some examples are shown below.

$$\begin{array}{r} 43.2 \\ - 9.1 \\ \hline 34.1 \end{array} \qquad \begin{array}{r} 20.3 \\ - 12.8 \\ \hline 7.5 \end{array} \qquad \begin{array}{r} 3.0132 \\ - 9.24 \\ \hline 2.7732 \end{array}$$

Multiplication. Multiply as if you were multiplying whole numbers, and mark off to the left as many decimal places in the product as you have in both the multiplier and the multiplicand. Example:

$$\begin{array}{r} 0.45 \text{ (2 decimal places in multiplicand)} \\ \times 0.4 \text{ (1 decimal place in multiplier)} \\ \hline 0.180 \text{ (3 decimal places in product)} \end{array}$$

Division. To divide one decimal fraction by another or by a whole number, divide as if you were dividing whole numbers. Mark off as many places in the quotient as the number of decimal places in the dividend exceeds those in the divisor. Two examples are shown below.

$$5.40 \div 2 \quad (\text{divisor}) \quad \begin{array}{r} 2.70 \text{ (quotient)} \\ 2 \overline{) 5.40} \text{ (dividend)} \\ \underline{4} \\ 1.4 \\ \underline{1.4} \\ 0 \end{array}$$

$$7.48 \div 2.2 \quad \begin{array}{r} 3.4 \\ 2 \overline{) 7.48} \\ \underline{6.6} \\ 88 \\ \underline{98} \\ 0 \end{array}$$

Converting Fractions to Decimals

To change a common fraction to a decimal fraction, divide the numerator by the denominator. For example,

$$1/4 = 1 \div 4 = \begin{array}{r} 0.25 \\ 4 \overline{) 1.00} \\ \underline{8} \\ 20 \\ \underline{20} \\ 0 \end{array}$$

Converting Decimals to Fractions

To change a decimal into a common fraction, omit the decimal point, write the denominator, and reduce to the lowest terms. Examples:

$$0.4 = 4/10 = 2/5$$

$$0.25 = 25/100 = 1/4$$

Exercise

- How are fractional quantities expressed in the metric system?

- Write three-thousandths as a decimal fraction.
- Add the following problems in decimal fractions.

$$\begin{array}{r} \text{a.} \quad 20.4 \\ + 10.1 \\ \hline \end{array}$$

$$\begin{array}{r} \text{b.} \quad 13.42 \\ + 0.923 \\ \hline \end{array}$$

- Subtract the following problems in decimal fractions.

$$\begin{array}{r} \text{a.} \quad 9.9 \\ - 2.7 \\ \hline \end{array}$$

$$\begin{array}{r} \text{b.} \quad 52.30 \\ - 1.60 \\ \hline \end{array}$$

- What is the rule for multiplying decimal fractions?
- Multiply the following problems in decimal fractions.

$$\begin{array}{r} \text{a.} \quad 0.61 \\ \times 0.3 \\ \hline \end{array}$$

$$\begin{array}{r} \text{b.} \quad 3.124 \\ \times 0.4 \\ \hline \end{array}$$

- Divide the decimal fraction 5.6 by 2.8.
- Convert the following fractions to decimals.
 - $1/2$
 - $3/8$
 - $1/6$
 - $3/5$
- Convert the following decimals to fractions.
 - 0.5
 - 0.75
 - 0.0175
 - 0.0475

B-4

Percentage, Ratio, and Proportion

Objectives: After completing this assignment, you will be able to—

1. convert percentages to fractions and fractions to percentages;
 2. convert percentages to ratios and ratios to percentages; and
 3. convert percentages to decimals and decimals to percentages.
-

Quite often it is necessary for the millwright to deal with percentages, ratios, and proportions. The purpose of the simple rules for conversion and the sample problems given in this assignment is to acquaint you with the types of problems you may encounter in various projects.

Rules for Conversion

The following examples illustrate the rules for converting percentages to fractions, ratios, or decimals; fractions, decimals, and ratios to percentages; and fractions of a percentage to fractions and ratios.

1. Percentage to Fraction

Example:

Convert 5 percent to a fraction.
Percent (%) means hundredths.
 $5\% = 5/100$

2. Percentage to Ratio

Example:

Express 5 percent as a ratio.
 $5\% = 5/100 = 1/20 = 1:20$
 $5\% = 1:20$

3. Percentage to Decimal

Example:

Express 5 percent as a decimal.
Omit the percent sign (%) and express the number in hundredths by using decimals.

$$5\% = 5/100 = 0.05$$

$$5\% = 0.05$$

4. Fraction to Percentage

Example:

Express $1/5$ as a percentage.
Multiply by 100 and add the percent sign (%).
 $1/5 \times 100 = 20$
 $1/5 = 20\%$

5. Decimal to Percentage

Example:

Convert 0.05 to a percentage.
Move the decimal point two places to the right and add the percent sign (%).
 $0.05 = 5\%$

6. Ratio to Percentage

Example:

Express the ratio 1:5 as a percentage.
Express the ratio as a fraction, multiply by 100, and add the percent sign (%).
 $1:5 = 1/5$
 $1/5 \times 100 = 20\%$
 $1:5 = 20\%$

7. Fraction of a Percentage to a Fraction or a Ratio

Example:

Express 0.5% as a fraction and as a ratio.

To change a fraction of a percent to a fraction or a ratio, add two zeros to the denominator.

$$0.5\% = 5/10 + 00 = 5/1,000 = 1:200$$

$$0.5\% = 5/1,000$$

$$0.5\% = 1:200$$

Ratio and Percentage

A ratio is another way of expressing a fractional part of a whole. Instead of writing the numerator above the denominator, the numerator is written first, followed by the denominator with either (-) or (:) between them.

Examples: $1/5 = 1:5$ (or $1:5$)

$$1/500 = 1:500 \text{ (or } 1:500\text{)}$$

In using words to denote a ratio, the expressions "one in five" or "one to five" (instead of one-fifth) or "one in five hundred" or "one to five hundred" (instead of one-five hundredth) are often used. In changing a ratio to a fraction, the first numeral becomes the numerator, and the second becomes the denominator.

Examples: $1-1,000 = 1/1,000$

$$3:200 = 3/200$$

The procedure for changing a ratio to a percentage or a decimal is, therefore, the same as that for changing a fraction to a percentage or a decimal. Converting a decimal to a ratio would be the same as converting a decimal to a fraction. Converting a percentage to a ratio would be the same as changing a percentage to a fraction.

Examples: Ratio to percentage: $1:5 = 1/5 = 20\%$

Percentage to ratio: $20\% = 20/100 = 1/5 = 1:5$ (or $1:5$)

Decimal to ratio: $0.55 = 55/100 = 11:20$ (or $11:20$)

Proportion

In mathematics a proportion is the statement of an equality or equal relationship between two ratios or fractions. Either (:) or (=) is used to express this equality.

Examples: $1:2 :: 2:4$

$$\text{or } 1:2 = 2:4$$

$$\text{or } 1/2 = 2/4$$

$$2:3 :: 4:6$$

$$\text{or } 2:3 = 4:6$$

$$\text{or } 2/3 = 4/6$$

In every true proportion expressed as equality between two ratios, the product obtained by multiplying the two middle numbers (the means) is always exactly equal to the product of the numbers at each end (the extremes). This can be illustrated using the same examples just given.

Examples: $1:2 = 2:4$

$$2 \times 2 = 4$$

$$1 \times 4 = 4$$

$$2:3 = 4:6$$

$$3 \times 4 = 12$$

$$2 \times 6 = 12$$

This fact gives us a very useful mathematical device, which is that, if any one or part of one of the factors is not known, we can determine the unknown. Two of the numbers can be multiplied, and the product of these two numbers can be divided by the third known factor to get the unknown factor. The procedure is just another application of the principle used in proving multiplication problems—that is, dividing the product by either multiplier or multiplicand gives the other number as a quotient. It is customary to represent the unknown by the letter x.

Example: $5:60 :: x:48$

$$60x = 240$$

$$x = 4$$

Proof: $5:60 :: 4:48$

$$240 = 240$$

Example: $5:(x - 32) :: 5:9$

$$5(x - 32) = 45$$

$$5x - 160 = 45$$

$$5x = 45 + 160$$

$$5x = 205$$

$$x = 41$$

Proof: $5:(41 - 32) :: 5:9$

$$5:9 = 5:9$$

$$45 = 45$$

Note that in the last example only part of the second factor is known. Both the x and -32 are multiplied by 5. In transferring it to the other side of the equation, the -160 is changed to a +160. When transporting a plus quantity to the other side of an equation, the number is subtracted or the sign is changed to minus (-).

Exercise

1. Convert the following percentages to fractions.
 - a. 5%
 - b. 20%
 - c. 40%
2. Convert the following fractions to percentages.
 - a. $\frac{3}{4}$
 - b. $\frac{1}{10}$
 - c. $\frac{3}{20}$
3. Convert the following percentages to ratios.
 - a. 5%
 - b. 20%
4. Convert the following ratios to percentages.
 - a. 1:10
 - b. 1:25
5. Convert the following percentages to decimals.
 - a. 8%
 - b. 87%
 - c. 3%
6. Convert the following decimals to percentages.
 - a. 0.08
 - b. 0.17
 - c. 0.98
7. Define the word **proportion**.
8. When a ratio is changed to a fraction, what does the first numeral become?
9. What is the rule for converting a fraction to a percentage?

B-5

The Metric System

Objectives: After completing this assignment, you will be able to—

1. discuss and work problems using metric weights;
 2. discuss and work problems using metric capacities; and
 3. discuss and work problems using metric lengths.
-

Introduction

The metric system is used to measure precise quantities of distance, capacity, weight, temperature, and pressure. The metric system is used in many countries. A variation of the English system is used in the United States, although there are many differences between the two systems. Many architectural plans and specifications now include all measurements in both English and metric designations. Metric measurements are usually shown below conventional dimensions.

In the eighteenth century, the French Academy of Science devised this system of measurement. It was developed on this basis: the unit of length, the **meter**, was to be one ten-millionth ($1/10,000,000$) of the distance from the equator to one of the poles of the earth. A meter equals 39.37 inches in the English system—a distance slightly more than 1 yard. To multiply or divide the meter, powers of 10 are used. Conversions in the metric system depend on changing the place of the decimal point. Study table 1 very carefully because it is the key to the metric system.

Using the prefixes shown in table 1 with the three units (gram, liter, and meter), the following unit measurements can be derived:

Weight

Milligram: $1/1,000$ of a gram (g) = 0.001 gram = 1 milligram (mg)
Centigram: $1/100$ of a gram (g) = 0.01 gram = 1 centigram (cg)
Decigram: $1/10$ of a gram (g) = 0.1 gram = 1 decigram (dg)
Dekagram: 10 grams = 1 dekagram (dkg)
Hectogram: 100 grams = 1 hectogram (hg)
Kilogram: 1,000 grams = 1 kilogram (kg)

Capacity

Milliliter: $1/1,000$ of a liter (l) = 0.001 liter = 1 milliliter (ml)
Centiliter: $1/100$ of a liter (l) = 0.01 liter = 1 centiliter (cl)
Deciliter: $1/10$ of a liter (l) = 0.1 liter = 1 deciliter (dl)
Liter: $1/10$ of a liter (l) = 0.18 dry pint or 0.21 liquid pint
Liter: 1 liter (l) = 0.908 dry quart or 1.057 liquid quarts
Dekaliter: 10 liters = 1 dekaliter (dkl)
Hectoliter: 100 liters = 1 hectoliter (hl)
Kiloliter: 1,000 liters = 1 kiloliter (kl)

Table 1
Metric System Prefixes

Weight—gram	Capacity—liter	Length—meter
Milli 0.001	Milli 0.001	Milli 0.001
Centi 0.010	Centi 0.010	Centi 0.010
Deci 0.100	Deci 0.100	Deci 0.100
Deka 10.000	Deka 10.000	Deka 10.000
Hecto 100.000	Hecto 100.000	Hecto 100.000
Kilo 1,000.000	Kilo 1,000.000	Kilo 1,000.000

Length

Millimeter: $1/1,000$ of a meter (m) = 0.001 meter = 1 millimeter (mm)
Centimeter: $1/100$ of a meter (m) = 0.01 meter = 1 centimeter (cm)
Decimeter: $1/10$ of a meter (m) = 0.1 meter = 1 decimeter (dm)
Dekameter: 10 meters = 1 dekameter (dkm)
Hectometer: 100 meters = 1 hectometer (hm)
Kilometer: 1,000 meters = 1 kilometer (km)

Converting Weight

The unit of weight in the metric system is the gram. The prefixes dealing with weights are in multiples of 10.

1,000 milligrams = 1 gram
1,000 grams = 1 kilogram
1 kilogram = 2.205 pounds
1 pound = 453.6 grams
1 ounce = 28.35 grams

Example: How many grams are in 3 ounces?

1 ounce = 28.35 grams
 $28.35 \times 3 = 85.05$ grams

Example: Convert 3 pounds to kilograms.

1 kilogram = 2.205 pounds
 $3 \div 2.205 = 1.36$ kilograms

Converting Capacity

The unit of capacity in the metric system is the liter (l).

1 liter = 1,000 milliliters
1 liter = 2.113 liquid pints or 1 liquid pint = 0.473 liter
1 liter = 1.057 liquid quarts or 1 liquid quart = 0.946 liter
1 liter = 0.264 liquid gallon or 1 liquid gallon = 3.785 liters
1 liter = 270.512 fluid drams or 1 fluid dram = 0.004 liter

Example: How many milliliters are in 2.6 liters?

1 liter = 1,000 milliliters
 $2.6 \times 1,000 = 2,600$ milliliters
(May also be worked by moving the decimal point three places to the right.)

Example: Convert 5 gallons to liters.

1 gallon = 3.785 liters
 $3.785 \times 5 = 18.925$ liters

Example: Convert 3,000 milliliters to liters.

1 liter = 1,000 milliliters
 $3,000 \div 1,000 = 3$ liters
(May also be worked by moving the decimal point three places to the left.)

Converting Length

Length is the distance covered by a straight line between two points. In the past, the standard for the meter was a piece of metal kept at Sevres, France. This piece of metal had two scratches on it, and the distance between these scratches was a meter. In 1960, the meter was redefined in terms of wavelengths.

1,000 meters (m) = 1 kilometer (km)
1,000 millimeters (mm) = 100 centimeters = 1 meter (m)
1 centimeter (cm) = 10 millimeters (mm)
1 inch = 2.54 centimeters (cm)
1 meter = 39.37 inches
1 kilometer = 0.6214 mile

Example: How many inches are in 5 meters?

1 meter = 39.37 inches
 $39.37 \times 5 = 196.85$ inches

Example: Convert 250 centimeters to meters.

1 meter = 100 centimeters
 $250 \div 100 = 2.5$ meters
(May also be worked by moving the decimal point two places to the left.)

Exercise

1. What is the relationship between the length of a meter and the earth?
2. How many liters are in 270 milliliters?
3. Convert 12 pounds to kilograms.
4. Convert 3,600 meters to kilometers.
5. How many grams are in 1 ounce?
6. How many inches are in 1 meter?
7. How many quarts are in 1 liter?
8. Convert 5 gallons to liters.
9. What is the unit of weight in the metric system?
10. How many grams are in 9 ounces?

B-6

Reading Blueprints

Objectives: After completing this assignment, you will be able to—

1. discuss the importance of understanding blueprints;
 2. describe the specific parts of blueprints that are necessary to the millwright; and
 3. discuss symbols and scales.
-

Importance of Blueprints

Before the millwright begins any installation job, a great deal of information must be known. The type of equipment to be installed will probably be heavy, may take up a great amount of space, and usually requires a certain type of base or platform. Blueprints of both the building and the equipment should be carefully studied. Blueprints will show whether the existing flooring is strong enough to support the equipment or whether special bases must be constructed.

Blueprints of the equipment will show exactly how the piece of equipment is constructed and how each part works in relation to the whole. By studying these blueprints, millwrights are able to install, dismantle, or repair and replace what is needed. Without blueprints, too much guesswork is involved, which is expensive and time-consuming.

Floor and Foundation Plans

The millwright should know how much weight is involved, then check the plans to understand the structural strength of the foundation and floor of the building. This information is usually found in the foundation plan and the floor plan of the building. These plans will also show the location of plumbing lines, sewer pipes, and electrical

lines. This means if you must build a foundation for the equipment, you can avoid digging up utility lines. Also, you will know where to "hook up" the equipment once it is installed. If walls have to be removed, you may need to check the building blueprints to see if extra support is needed for the roof. This will be shown in the framing plans.

Specification Sheets

Specification sheets clearly define every item that has not been shown elsewhere on the plans. They will tell you such things as gauges of metal used, types and sizes of pipes, concrete mixtures, lumber classification in the building, type of hot-water supply, and wiring codes. This will give you a better idea of the utility supply available and what extra facilities must be installed to operate the equipment. When doing repair work or maintenance later, the specification sheets may be helpful in troubleshooting.

Detail Sheets

When working on or installing the equipment, you will need blueprints and detail sheets of the specific piece of equipment. You will need to know the internal and external construction and movement of the equipment. Detail sheets provide this

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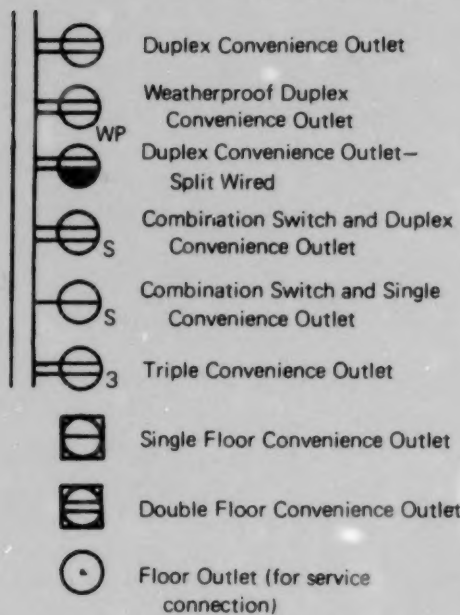


Fig. 1. Electrical symbols

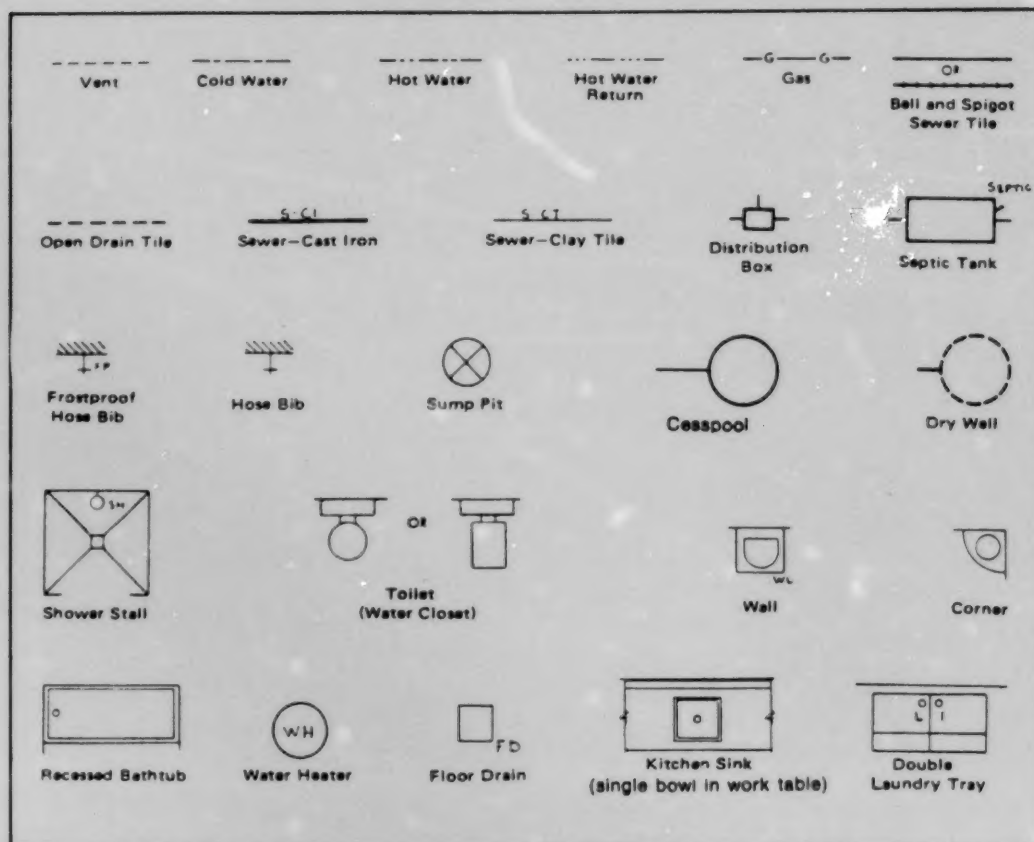


Fig. 2. Common plumbing symbols

information. They have "blowups" on them, which show small parts in larger detail. Exploded views may be included to show how each part fits into a particular assembly.

Symbols

Because floor plans are so small after they have been scaled down, it is impossible to draw in all the details. Therefore, symbols are used to give definite meaning for a number of items. The most important symbols to learn are those for electricity, plumbing, heating, and materials. Also important are symbols that show openings in walls and partitions. Most symbols are standardized and can be easily understood. Figure 1 shows some of the electrical symbols you should know, and common plumbing symbols are given in figure 2.

Scales

Learning how to use a scale would be helpful when you are studying blueprints. All dimensions may not be given on the blueprint. This means that you must check a distance on the blueprint with a scale in order to arrive at a specific dimension you will need. The architect's scale (fig. 3) is usually triangular in shape and made of wood or plastic. It has 11 scales in all. The

full-size scale is divided into sixteenths of an inch. It is easily located by finding the number 16 that is stamped on one end of the scale. Other scales used are $\frac{3}{32}$ inch, $\frac{1}{8}$ inch, $\frac{3}{16}$ inch, $\frac{1}{4}$ inch, $\frac{3}{8}$ inch, $\frac{1}{2}$ inch, $\frac{3}{4}$ inch, 1 inch, 1 $\frac{1}{2}$ inches, and 3 inches to the foot. Each of these designations is stamped on one end of the scale.

Exercise

1. What is the disadvantage of not working with blueprints?
2. What plans are used to understand the structural strength of the foundation and floor of the building?
3. Why should you know the location of utilities?
4. Why might framing plans be important?
5. Where may types and sizes of pipes be found?
6. What information do detail sheets provide?
7. What does an exploded view show?
8. What is used to identify parts and materials on scaled-down floor plans?
9. Why should you know how to use an architect's scale?
10. How many scales does an architect's scale have?
11. How are these scales designated on the architect's scale?

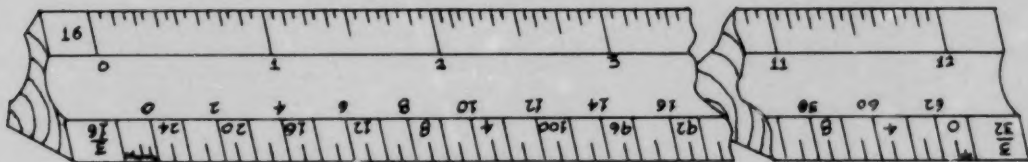


Fig. 3. The architect's scale

C-1

Layout and Measuring Tools

Objectives: After completing this assignment, you will be able to—

1. give the uses of measuring and squaring tools;
 2. discuss the uses of tools used for transferring measurements; and
 3. discuss layout and leveling tools.
-

Measuring tools refer to devices that are used to determine linear or angular measurement. **Linear measurement** is the measurement of distance on a straight line between two points. **Angular measurement** is the measurement of angles, trueness of surfaces, and relationships between surfaces.

Tools that may be used to measure include rules, steel tapes, try squares, combination squares, speed squares, and framing squares. Used with these tools are tools designed for transferring measurements from scales to the work or from the work to scales. Examples of such tools are dividers, inside calipers, outside calipers, and tram-mel points. Some of the tools that may be used to take angular measurements are the level, the sliding T bevel, the protractor, and the plumb bob and line.

Other types of tools used in measuring distances, angles, and shapes on specific types of work are classified as gauges. Examples are marking gauges and butt gauges. Tools such as scribes and punches are used for marking lines and locations.

The term **graduation** is used to identify the units or divisions on a measuring device. Although some measuring devices are divided into metric units, most mechanical units are broken into inches. On most rules the inch is divided into halves, 4ths, 8ths, and 16ths.

To achieve a finer degree of measurement, the inch may be divided into 32nds and 64ths. The fractions of an inch are represented by lines of varying length placed on the edge of the rule perpendicular (at a 90-degree angle) to it. Each inch on the rule is numbered, but ordinarily the divisions are not. Instead, the smallest division is usually numbered one time on the face of the scale or rule. You can purchase scales or rules with figured graduations if you desire.

Linear Measurement and Squaring

Straight Rule. The 1-foot, 2-foot, and 3-foot (yardstick) rules are used for marking or measuring when doing small jobs. One side of the rule is usually divided into 8ths of an inch and the other side into 16ths of an inch. This rule has a tendency to warp, so you should not use it as a straightedge.

Folding or Zigzag Rule. The folding or zigzag rule (fig. 1) comes in several lengths, but the 6-foot length is most common. Although generally made of maple, it can also be found in steel, aluminum, and plastic. Wood is the most popular material for most uses because it is tough and flexible, is not greatly affected by corrosion and moisture, and will not conduct electricity.

The sections of folding rules are usually from 7 1/2 to 8 inches long except for the

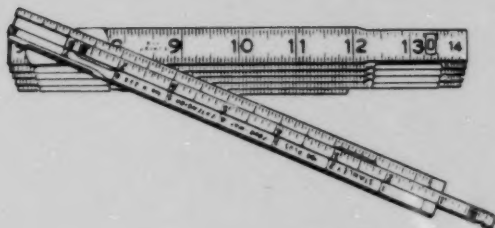


Fig. 1. Folding extension rule

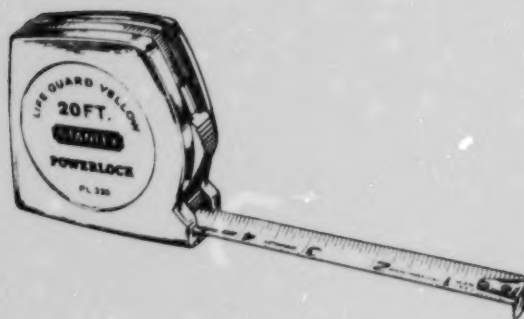


Fig. 2. Tape rule



Fig. 3. Try square

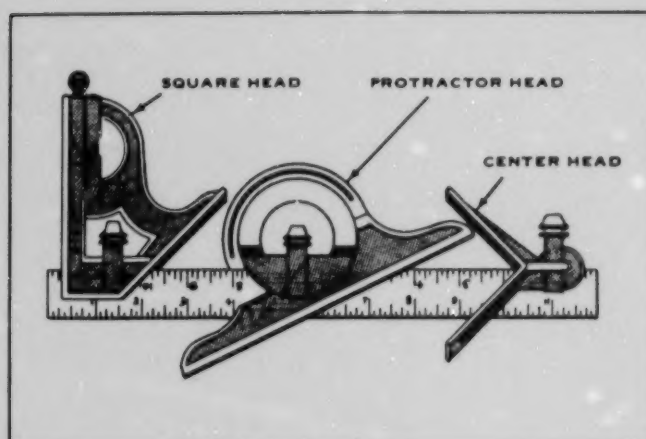


Fig. 4. Combination square

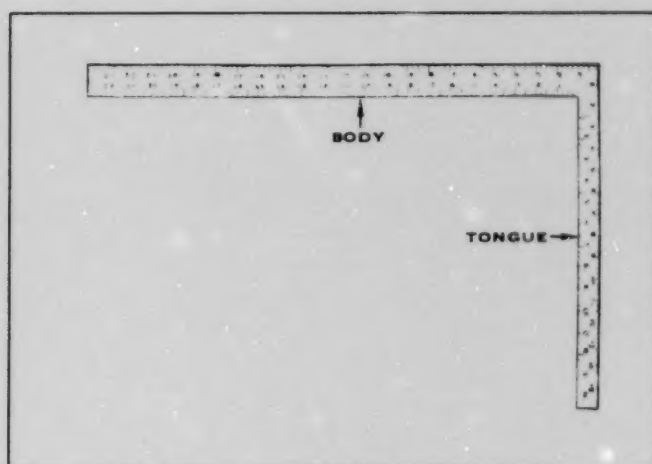


Fig. 5. Framing square

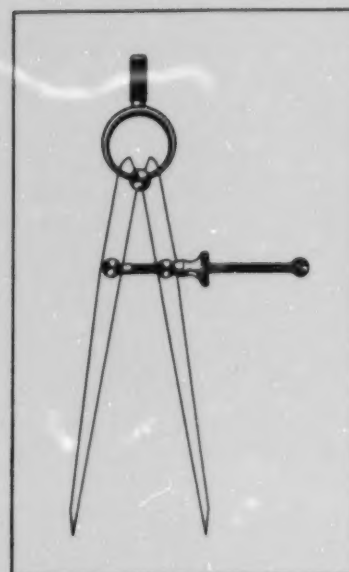


Fig. 6. Spring dividers

first and last sections, which are shorter. Even so, each section adds only 6 inches to the length of the rule. This is because the extra length is used in the overlap between adjoining sections. The length of a rule is determined by the number of sections it has. Good folding rules have metal caps on the ends of the first and last sections to provide firm, square ends for measuring and to prevent damage to the end when the rule is butted against a wall or other object.

Folding rules have many types of graduations. The most common system uses consecutive inches divided into 16ths of an inch on both edges of both sides. The rule is read from left to right, with the numbering beginning on the outside of the first and last sections. The graduations are usually printed in jet black for better viewing.

Tape Rule. The tape rule is a combination of the tape and the rule. It has a tempered spring blade that is usually 1/2-inch, 5/8-inch, or 3/4-inch wide and 6 to 12 feet long. The blade is concave and projects straight out for taking vertical or horizontal measurements. Yet, it is flexible enough to measure circumferences of cylindrical objects. Most rule cases are either round or D-shaped, as shown in figure 2. Some tape rule blades are withdrawn from the case and returned to it manually, but others are equipped with an automatic spring rewind inside the case. When a button is pushed, the tape retracts automatically into the case.

Measuring Tape. Tapes are sometimes needed for measuring long lengths such as foundations or long rooms. The measuring tape may be either steel or woven. These tapes are always flat rather than concave. The case for the long measuring tape consists basically of a winding drum and handle mounted into a flat, cylindrical case. The rewind handle on most tapes is the type that folds flat against the case and is opened by a push pin on the back of the case.

Try squares. The try square (fig. 3) is used for laying out and measuring as well as for squaring small materials. The handle may be of wood or metal, and the blade is usually made of steel with graduations of 8ths of an inch stamped on the outside edge of the blade.

Combination Square. The combination square (fig. 4) comes with three different types of heads—the square head, the center

head, and the protractor head. Each head is used separately with a common blade, usually 12 inches long. A central groove runs down the length of the blade so that each head can be slid to different locations on it, then locked to it. The scales on the blade may have any desired graduations, but they are usually marked in 8ths, 16ths, 32nds, and 64ths of an inch. The center head is used for squaring and laying out lines at 45- and 90-degree angles.

Framing Square. The framing square (fig. 5) is used in all phases of squaring. The longer, wide part of the square is the body, or blade, and the shorter, narrow part is the tongue. On the standard framing square, the body is 24 inches long and 2 inches wide, and the tongue is 16 inches long and 1 1/2 inches wide.

Tools for Transferring Measurements

Dividers. Dividers are used to scratch, or scribe, arcs and circles on metal and to transfer measurements on paper, wood, and metal. The tool has two hardened points. One point is placed on the center of the arc or circle, and the other is used to scribe the line. Dimensions can also be picked up from a rule and transferred to a drawing or layout.

The chief types of joints are firm and spring. Spring dividers with an adjusting screw are the most popular type (fig. 6). They are more quickly and accurately set than those with firm joints, which must be adjusted by hand. Spring dividers have a knurled fulcrum stud which can be adjusted and used to rotate the tool between the fingers. One type of spring divider has a quick-acting adjusting nut that is split. This feature permits it to engage the screw at approximately the correct position. Then the final adjustment is made by turning the nut, rotating it between the fingers.

Trammels (Trammel Points). Trammels (fig. 7) are used for arcs and circles too large to be scribed with dividers or drawn with compasses. They are also known as trams or beam compasses. The tool consists of two points that slide on a wooden or steel beam, which is 10 inches or longer. You can lock points at any position on the beam with a thumbscrew. One point may be adjusted with an adjusting screw in the same manner as spring dividers. Some trammel sets come

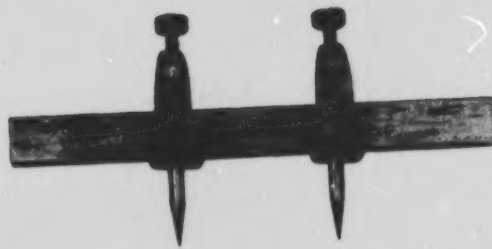


Fig. 7. Trammel points

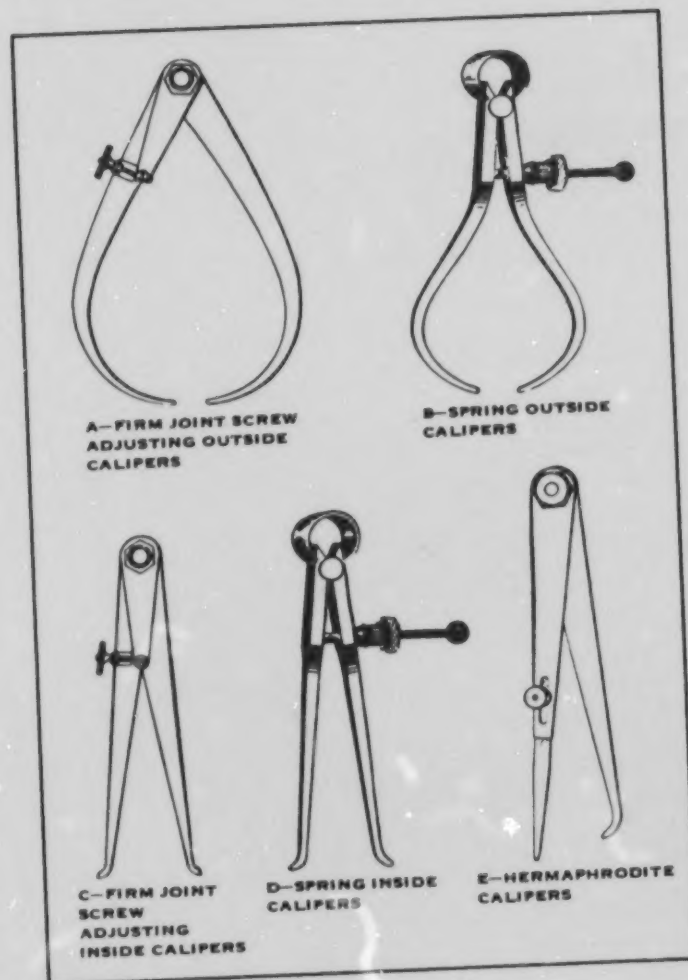


Fig. 8. Calipers

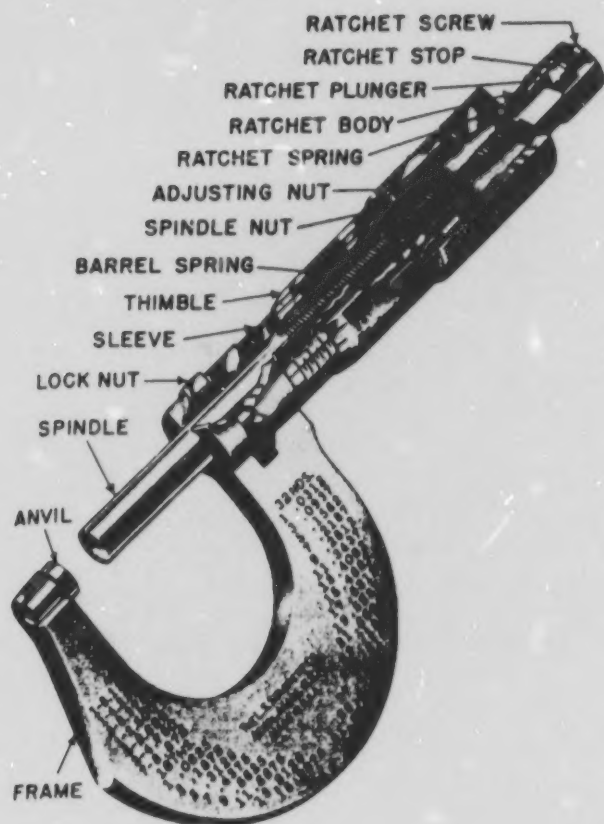


Fig. 9. Micrometer caliper



Fig. 10. Sliding T bevel

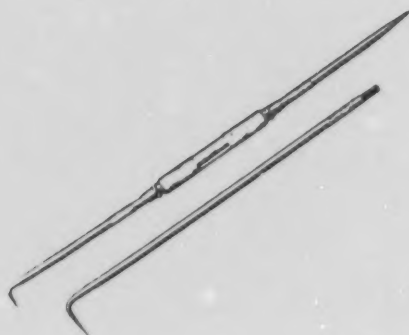


Fig. 11. Scribes

with interchangeable outside and inside caliper points to be used when the measurement is too wide for ordinary calipers.

Calipers. Calipers are used to transfer measurements from measuring tools to the work or from the work to measuring tools. They are used quite often on wood or metal-working lathes. There are three general types of calipers: **outside**, for transferring outside measurements; **inside**, for transferring inside measurements; and **hermaphrodite**, for laying off lines parallel to an edge of the work and for locating the center of round material quickly. These various calipers are shown in figure 8.

Micrometers. The **micrometer** or **micrometer caliper** (fig. 9) is a measuring tool used primarily for reading to thousandths of an inch. It works on the principle of recording the advance of a fine-pitch screw through a number of turns or fractions of turns. Measurements are taken between the anvil and the face of the spindle. The threaded spindle screws inside the barrel, which is rigid with the frame. The spindle is joined to and turned by the thimble, causing the thimble to follow the spindle as it is screwed in and out of the barrel. The thimble has one end beveled, upon which 25 divisions for reading fractions of a turn are cut. On one side of the barrel, parallel to its axis, a 1-inch index line is drawn. It is graduated into 40ths of an inch, with every fourth graduation numbered from 0 to 10.

The ratchet stop halts the advance of the spindle when the proper amount of tension is put on the object being measured. It also may be used for turning the thimble. The C-shaped frame is rigidly constructed. This keeps it from warping or springing with use and provides clearance for the work. The faces of the spindle and anvil are parallel planes and may be locked in position by means of the knurled clamp ring.

Sliding T Bevel. The sliding T bevel (fig. 10) has a blade that may be clamped at any desired angle with the handle. It is available in several sizes and with either wooden or metal handles. It is especially useful in laying out angle cuts that are transferred from an existing object or layout. To set the angle, loosen the thumb-screw on the end of the handle, and place the handle against one leg of the angle and

the blade against the other leg of the angle. Then tighten the blade in the handle.

Marking and Leveling Tools

Scribers. The scribe is a sharp-pointed tool used for scratching lines on sheet metal along a straightedge and for tracing the outline of a **template** (pattern). Since you need a clean-cut, sharp line for accurate work, you will prefer the scribe to a pencil. The scribe shown in figure 11 has two hardened points. One is straight and the other is bent at a right angle for use in recesses. When used with a straightedge, you would hold it somewhat as you would a pencil. It is inclined at a slight angle so that only the sharp point touches the bottom of the straightedge. Take only one firm stroke with the scribe. Retraced lines are often confusing and inaccurate. The scribe is sometimes called a **scratch awl**.

Punches. Center punches, prick punches, and pin punches are used often by the millwright. **Center punches** (fig. 12) are used primarily to make indentations in metal for starting a drill. They are also used to mark points in layout work on heavy metal and sometimes to make indentations in hardwoods for starting drills.

Prick punches (fig. 13) have sharper points than center punches. They are used primarily to mark centers and other points in layout work on sheet metal or other materials softer than steel.

Pin punches come in three designs and have several different uses. The taper-pin punch is used to drive both tapered and straight pins into shafts and for other similar uses (fig. 14A). The long straight-pin punch has the same purpose (fig. 14B). A long taper-pin punch, also called an aligning punch or drift (fig. 14C), is used to align rivet and bolt holes in sheet metal parts.

Pin punches are useful in punching out rivets from sheet metal work. In this operation, you select a punch almost the same size as the rivet hole. A punch that is much smaller than the rivet shank upsets (indents) the end of the rivet and makes it swell in the hole.

Carpenter's Level. A carpenter's level is used to determine whether or not a surface is level or plumb. The term **level** refers to any straight line or plane that is

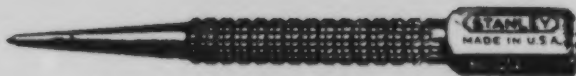


Fig. 12. Center punch

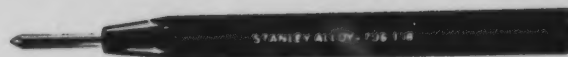


Fig. 13. Prick punch

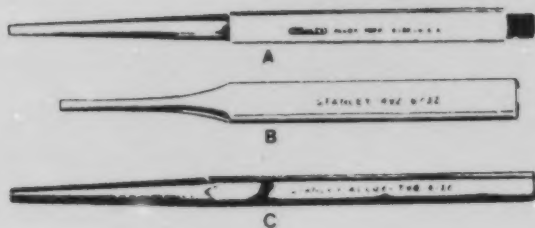


Fig. 14. Types of pin punches

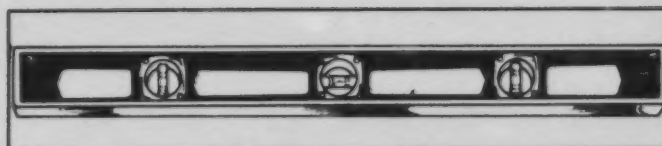


Fig. 15. Carpenter's level

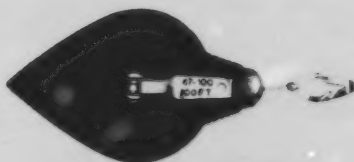


Fig. 16. Chalk-line reel

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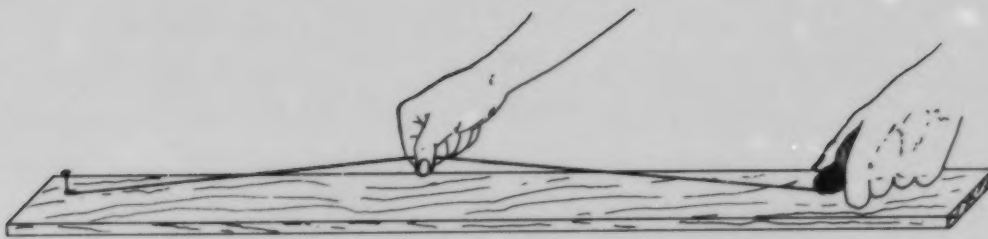


Fig. 17. Striking a chalk line



Fig. 18. Plumb bob

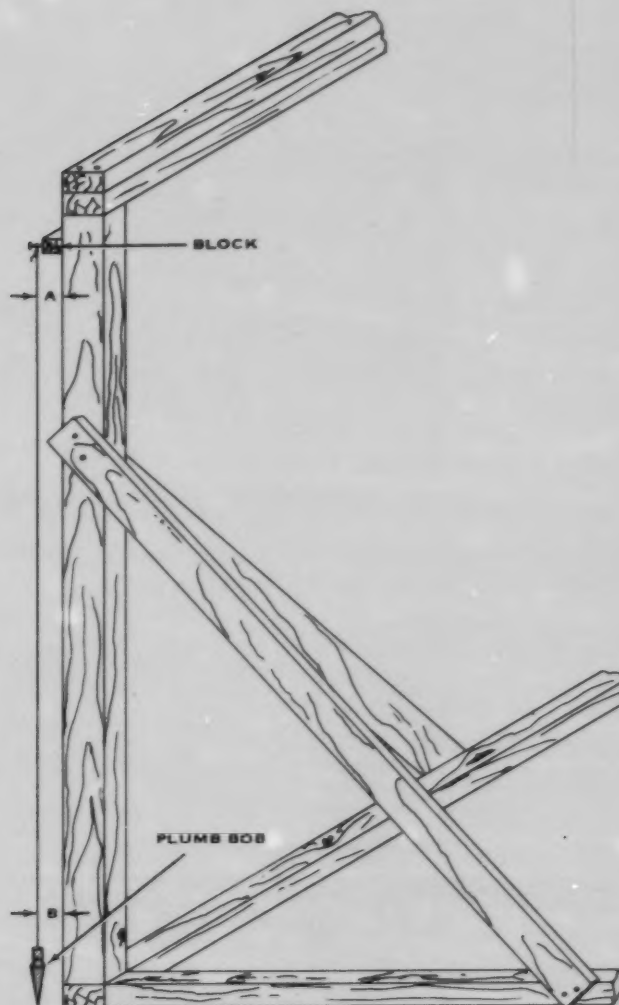


Fig. 19. Plumbing a corner

horizontal or parallel to the surface of a body of still water. The term **plumb** refers to a line or plane surface that stands upright or forms a right angle with a level surface. The carpenter's level (fig. 15), sometimes called a spirit level, is made of hardwood, aluminum, or steel and is usually from 24 to 28 inches long. The level has one or more closed glass cylinders filled with liquid. A small air bubble is left in the glass cylinder. This bubble will be centered between two marked lines when the glass tube is in a horizontal position. Some levels also have glass tubes placed perpendicular to the bottom of the level to check vertical positions.

Chalk-Line Reel. A chalk line is used to mark long, straight lines on lumber, concrete, or other materials. The chalk-line reel (fig. 16) is especially handy for holding, winding, and unwinding this line. The reel is filled with powdered chalk that adheres to the line and remains on it after the line has been unreeled. You hold the line taut and snap it on the surface to be marked, which dislodges the chalk from the line and deposits it on the surface in a straight line (see fig. 17).

Plumb Bob. The plumb bob (fig. 18) is used for vertical layout and checking. It consists of a weight with a pointed end suspended on a cord fastened to the center

of the plumb bob. When the plumb bob is suspended, the string or cord is in a vertical position. To use the plumb bob, tack a block of wood onto the object to be plumb, as shown in figure 19. Hang the plumb bob line on a nail driven into the block, and when the plumb bob stops moving, the line will be in plumb.

Exercise

1. What is linear measurement?
2. How does the term **graduation** apply to measurement?
3. What is the shape of a tape rule blade?
4. What is a try square used for?
5. Name the three types of heads used on a combination square.
6. Why are spring dividers more popular than firm dividers?
7. Where are measurements taken on a micrometer?
8. Where are T bevels especially useful?
9. What is the purpose of a long taper-pin punch?
10. What is another name for a carpenter's level?
11. How is a line drawn with a chalk-line reel?
12. What is a plumb bob used for?

C-2

Handsaws

Objectives: After completing this assignment, you will be able to—

1. name the various types of handsaws used by the millwright;
 2. explain how to use handsaws; and
 3. discuss handsaw maintenance and safety.
-

Types of Handsaws

The common name **handsaw** usually refers to the type shown in figure 1. It is a very simple tool that consists mainly of a blade and a handle. With reasonable care, very little can happen to a saw to prevent it from operating properly. The handsaw used for rough carpentry work has coarser teeth than the one used for finish work. A saw's coarseness or fineness is determined by the number of points per inch. Sawteeth are considered **set** when every other tooth is bent to the right and the remaining teeth are bent to the left. This makes the saw cut, or **kerf**, wider than the blade of the saw. This helps prevent binding or pinching.

The size of this saw is determined by the blade length, which varies from 20 inches to 28 inches. The 24-inch or 25-inch lengths are considered standard.

In good quality saws, the saw blades are ground so that they taper from the back to the toe. They are also tapered from the cutting edge toward the back edge of the blade. Tapering is an asset because it makes the saw lighter and less likely to pinch. It also adds stiffness to the blade.

Crosscut Saw. The crosscut saw, designed to cut across the grain, is the most common handsaw used by the millwright. You will probably prefer a crosscut saw with 7 or 8 points per inch for sawing rough cuts or for more general work.

Ripsaw. At first glance, the rip saw looks like the crosscut saw. However, the teeth of the rip saw are shaped like small chisels, rather than the knife points used on the crosscut saw. Since the rip saw is used for cutting with the grain of the wood, the set of the teeth is not as great as that of the crosscut saw. **Set** refers to the distance that the sawteeth are pushed away from the saw's center line. For most jobs, you should select a rip saw with 5 1/2 to 7 points per inch, and a length of from 24 to 26 inches.

Hacksaw. The hacksaw (fig. 2) is used mainly for cutting metal. You may need it to cut reinforcement rods, nails, or heavy metal sheets. The hacksaw has a strong, rigid adjustable steel frame with removable blades. It is available in many types and sizes.

Using Handsaws

When using the crosscut saw or the rip saw, you must first lay off the rule lines to be cut. Always check the measurements again before starting to saw. This avoids costly cuts because of a misread rule. The mark should be clear so you are able to saw close to the line. Place an X or some other identifying mark on the waste material. This ensures that you do not accidentally saw on the wrong side of the line.

The material to be sawed should be secured in a vise or placed over sawhorses



Fig. 1. Handsaw



Fig. 2. Hacksaw

so that it does not vibrate or move around during the sawing operation. If you are right-handed, hold the saw in your right hand, with the index finger extended along the side of the handle. Place your left hand on the material, and use your thumb as a guide for the saw blade until the cut has been started. Exercise caution in keeping your thumb away from the teeth. The cut should be started on the back stroke several times until the kerf (saw groove) is begun.

Hold the crosscut saw at an angle of 45° to the work surface and the rip saw at an angle of 60°. The blade should follow the marked line on the waste side. The saw blade should be held at a 90° angle (right and left of the blade) with the face of the material being cut. When making final strokes, hold the end of the material so that the end does not drop and cause the material to split. If the saw is not held 90° from the face, or has become dull or lost its set, pinching may occur. The teeth must be sharp and set for the saw to work effectively.

Maintenance of Handsaws

Handsaws must be handled very carefully to keep the teeth from becoming dull. Keep them in special racks while in the shop. Most workers either hang the saws on the wall or store them in a toolbox. If you place them in a toolbox, keep them away from other tools. The teeth edges should be placed against wood or wrapped with cloth. Since all cutting edges rust easily, you should rub a thin layer of oil on them, as well as on the rest of the blade, before storing the saw.

After you use the hacksaw, loosen the frame tension on the blade to prevent undue strain. Keep saws sharp and set through periodic checks.

Safety

Safety rules should be observed at all times when using, sharpening, or storing handsaws. Saws lying around cause many serious accidents. Keep your hands away from the teeth when sawing. Do not allow other workers near a sawing operation. If the sawteeth are large and you apply too much pressure at the start of the cut, the saw may buckle and cause injury. Do not allow the saw to come the whole distance out of the saw kerf, or the saw will come free and cause nicks in the wood or injury to a worker.

Exercise

1. What is the difference between the teeth of handsaws used for rough carpentry and those used for finish work?
2. How are good quality saw blades ground?
3. What handsaw is designed to cut **across** the grain?
4. How are rip saw teeth shaped?
5. At what angle should you hold a cross-cut saw when sawing?
6. What are the identifying characteristics of a hacksaw?
7. What should you do immediately after using a hacksaw?
8. What does the term **set** mean on a handsaw?
9. What does set prevent?
10. How should you secure the material to be sawed to prevent movement?

C-3

Files, Rasps, and Snips

Objectives: After completing this assignment, you will be able to—

1. identify various types of files and rasps;
 2. give the procedures to use when filing; and
 3. identify various types of sheet metal snips.
-

Files and Rasps

Files are important hand cutting tools that are used in almost all mechanical trades. They can be easily abused if they are not used correctly. Typically, you push the file across the work surface to remove excess material and bring the piece into its proper dimensions. Teeth in the surface of the file provide the cutting action. These teeth "bite" into the material, remove a small chip, and carry it away from the work surface in the openings between the teeth.

The rasp is really a type of file, but it has much coarser teeth. It is used mostly for cutting and smoothing wood, while the typical file is used on metals.

Figure 1 shows the various parts of a file. The terms apply to all standard files, regardless of length and shape. The length of the file is the distance from the point, or toe, to the heel and does not include the tang. Generally, the length of the file is its cutting surface. Standard files come in lengths of from 4 to 18 inches. Files from 4 to 10 inches long are graduated in inches. Files longer than 10 inches are graduated in 2-inch lengths. The only exception to the rule is the triangular section file.

The **face** of a file may be either one of its two widest surfaces. Teeth are usually cut on the face at a 65° to 85° angle. In the

case of a square file, all four sides are considered faces. On a standard file, the edge is the narrowest surface. Teeth are usually cut on these edges and are often coarser than those found on the faces. Teeth on file edges enable the user to cut square shoulders, notches, or special shapes. Often it is important to avoid cutting a surface next to the one being filed. Special files are made for this purpose. They have uncut edges and are known as safe edge files.

The **point**, or **toe**, is the end opposite the handle. The **heel** is that portion next to the handle. It has a shoulder that prevents the handle from slipping onto the file body. The heel is usually stamped with the manufacturer's name, the shape, and the cut of the file.

The **tang** is the tapered portion of the file that extends beyond the heel. The handle slips onto this portion. It is tapered to hold the handle securely when properly applied. A handle that has been rapped lightly into place may be removed by rapping lightly in the opposite direction. A file should never be used without a handle.

Designation. To buy or specify a file correctly, three things must be designated: (1) length, (2) shape, and (3) cut. For example, the phrase "a 10-inch, flat, bastard file" identifies one file from among dozens

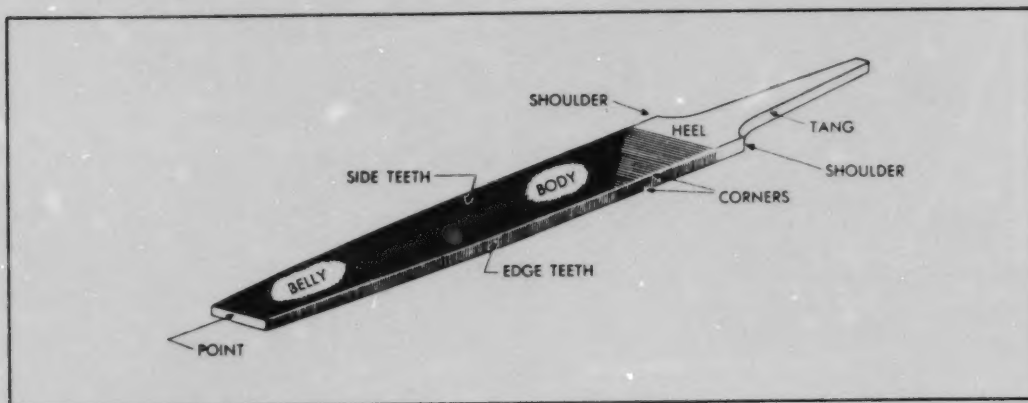


Fig. 1. Parts of a file

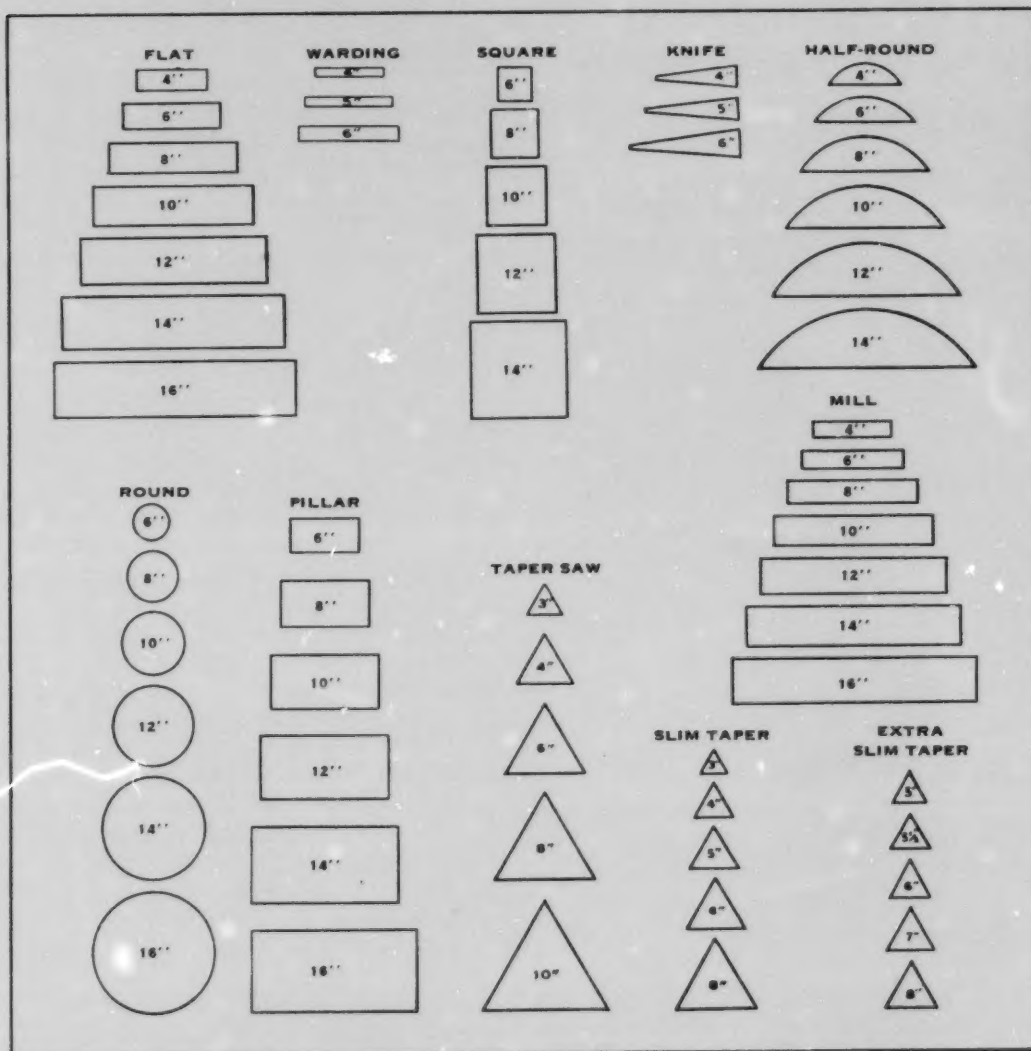


Fig. 2. Cross-sectional views of commonly used files

of other files. The term "10-inch" identifies the length, "flat" tells the shape, and "bastard" is the cut of this particular file.

One exception to this rule is the specification for a particular kind of a single-cut file known as a mill file. This file comes in three grades of coarseness. It is used as a sharpening device for many other tools.

Another exception is the saw file. This special-purpose file comes in only one cut, which makes it unnecessary to specify the cut. A 5 1/2-inch, slim taper file or a 6-inch extra slim taper file are appropriate designations.

Shape. File shapes are usually classified into rectangular, triangular, and circular. Names usually describe the shapes, such as flat, half-round, and square. File shapes are then further divided into bellied and blunt. Figure 2 shows cross-sectional views of the most commonly used files.

The bellied file is straight from the heel for a third of its length. From this point to its toe, it is slightly curved. Blunt files are straight the entire length of the file. You can buy all of the standard sizes in blunt files, but you must specify the name. For example, the description of one file would be "10-inch, blunt, round bastard file." These blunt files are used for final smoothing operations where a light, accurate cut must be taken.

The various shapes and sizes of files are intended to accommodate the general shape of the surface being filed. Flat and mill files are used on flat surfaces. Round files are used to enlarge round holes or small fillets (grooves). Half-round files are used on large curves and curved surfaces. Square files are used to enlarge or make square openings. Tapered files are used for sharpening saws and cutting V-shaped notches. Warding files are used for very narrow slots, and knife files are used for very sharp, angular slots.

Cut. The cut of a file designates the shape of the teeth and the manner in which the file is cut. The single-cut file is made by taking a file blank and repeatedly striking it with a full-width chisel as the blank is moved along. At each stroke, the chisel raises a long, straight cutting edge known as the file tooth. The single-cut file has a long, knife-sharp tooth edge that removes a curled chip when pushed across the work.

Double-cut files are made by cutting a single-cut file a second time. The second cut is made at a 40° to 45° angle from the center line of the file. This results in a diamond-shaped tooth, uniformly spaced along the file. A diamond-shaped tooth removes material much more rapidly than a chisel-shaped, single-cut tooth. A single-cut file is used to smooth or finish the work after a double-cut file has been used.

The coarseness of the file depends upon how rapidly the blank is moved beneath the cutting chisel. This coarseness is in three grades, known as bastard (coarse), second-cut (medium), and smooth (fine).

Handles. Never use a file unless it is fitted with a handle. The handle should be tight enough that it will not come off easily when used. There are many types of file handles. The most common type is wood, with a metal ferrule to prevent it from splitting. Wooden handles usually come with a tapered hole to fit the tang of several file sizes. Place the file tang in the hole, then tap the butt of the handle against the bench, sinking the file tang into the handle. To remove the handle, grasp the file and tap the handle off on the edge of a table or bench. Some handles have self-threading or spring-tension ferrules that lock them on the file tang. Others have a setscrew on the side of the ferrule that screws down on the tang.

Using Files and Rasps

When possible, hold the work in a vise. The vise is rigidly fastened to a bench or table to allow no movement during filing. The vise also makes it possible to place work in the best position for getting the job done. When work might become damaged by the knurled jaws of the vise, insert scrap wood on each side of the material to be filed or rasped. If objects cannot be placed in a vise or clamped securely, rest them on some object and hold with one hand.

A proper body position when filing at the bench is important. It can eliminate tiring and uncontrolled file strokes. Place the feet about 2 1/2 feet apart. This allows the arms to swing in a line with the cut.

Be sure the handle is on the file. Hold the file in both hands with the butt of the file handle in the palm of the right hand. The fingers should encircle the handle, and

the thumb along the top. Hold the point or toe of the file between the thumb and index finger of the left hand. Thumb pressure on top allows variation between light and heavy pressure required by the type of cut. Apply just enough pressure on the file to keep it cutting.

The stroke of the file should be at a rate of from 30 to 50 strokes a minute. Never take fast strokes, and **always** lift the file from the work on return strokes to keep from dulling the file.

Drawfiling is done by pushing a mill file sideways over a metal surface (usually an edge). Take care to apply equal pressure with both hands so the file cuts uniformly. The forward stroke, away from the body, is the cutting stroke. The handle should be on your right.

General Care

A file is made from the brittlest, hardest steel known. Anything that will dull any sharp edge will dull file teeth. For example, laying files across other files or tools, dropping them on concrete floors, striking them against hard objects, and tossing them into drawers are all extremely bad habits. A file is only as efficient as its teeth are sharp. Store files in a rack when in the shop. If you must carry files or rasps to other locations, wrap them or keep them apart from other tools.

If files must be stored in a drawer, separate them from other tools by partitions. Files and rasps clog easily with chips. To prevent clogging, tap the point of the file against the heel of the hand or a wooden bench every few strokes to keep the teeth free of chips.

Occasionally, you must "card" the file with a file card. A file card is a brush that has fine wire bristles on one side and sometimes a fiber bristle brush on the other. The fiber bristles are used first to clean the file by brushing across it in the direction of the parallel teeth. The card is then turned over, and the file is brushed with the wire bristles. Putting chalk on the file teeth prevents clogging to some extent. A file needs a correctly fitted handle.

Files must be kept dry and free from rust. Never use a file as a pry bar. Not only may the file break, but also any bending of the tang will hurt the file's effective-

ness. Hitting the file with a hammer usually shatters it, and could injure the user.

Snips

As you will be doing various jobs requiring the use of sheet metal, you should know what types of snips to use.

Straight-pattern snips (fig. 3) are used for straight-line cuts and are available in lengths from about 7 inches to 13 inches. They can be used easily to cut out small notches where bends are to be made.

Aviation snips (fig. 4) are usually 8 to 10 inches long and come in three different styles. The straight-cutting style can be used to cut in either direction, although the right-hand and left-hand styles are made particularly for those types of cuts. Some people have trouble telling these last two styles apart, but they are easy to identify. When you are ready to cut the metal, if the upper blade is on your right, the snips are used to cut right-hand curves. If the upper blade is on your left, use them to cut left-hand curves. Aviation snips are the most popular of all hand snips.

You may also use hawk bill, circular, bulldog (heavy metal), combination, bench, and compound lever snips. Compound lever snips are also used for heavy cuts.

Cutting with snips is much like cutting with scissors. Always see that the blades are tight, but not so tight as to cause excessive binding. Hold the blades at a 90° angle to the material to avoid making bevel cuts through the thickness. Remove any surplus material with rough cuts before cutting to the line. Do not cut completely to the end of the snips as this may tear the metal and make a jagged cut. Make short cuts, but keep the blades against the metal while cutting. Keep your hands away from the sharp edges of the metal during handling. File any jagged edges after cuts have been made.

Exercise

1. What must you use on the tang of a file or rasp?
2. Why are teeth cut on file edges?
3. What is usually stamped on the heel of the file?
4. What three things must be designated when buying a file?

5. What are the three grades of coarseness for files?
6. For what are tapered files used?
7. How are double-cut files made?
8. How fast should the stroke of the file be?
9. What tool is used to clean a file?
10. What usually happens when a file is hit with a hammer?
11. What are the three different styles of aviation snips?
12. Which aviation snips are used to cut right-hand curves?
13. What should be done before using snips to cut to the line?
14. What should you do after making sheet metal cuts?

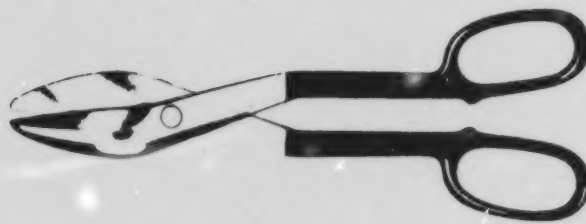


Fig. 3. Straight-pattern snips

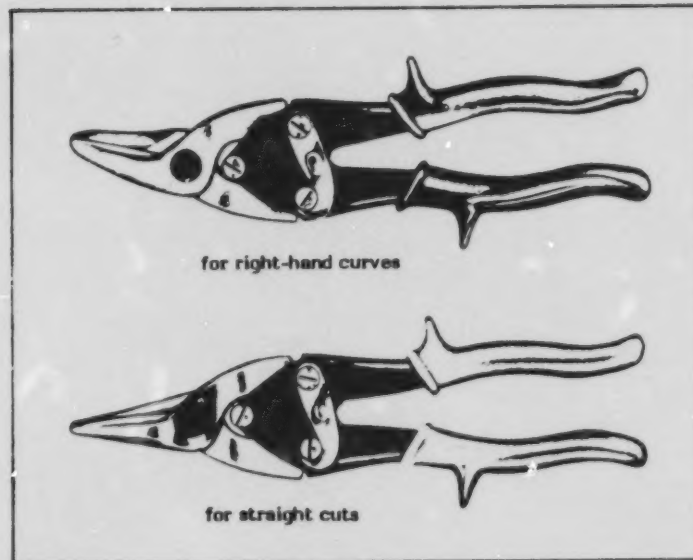


Fig. 4. Aviation snips

C-4

Pounding and Driving Tools

Objectives: After completing this assignment, you will be able to—

1. discuss the types of hammers and mallets and their uses;
 2. describe the various types of screwdrivers and their uses;
and
 3. give the methods of caring for and maintaining pounding and driving tools.
-

Hammers

The hammer is a simple tool that has a head and a handle. The head is the face or the driving surface used for hammering nails into any soft material. The poll, or neck, connects the face or driving surface to the hammer body. The claws are used to provide a pulling action for removing nails. The socket, or eye, connects the handle and the head. Steel-handled hammers are forged so that handle and hammer are of one piece of steel.

Types of Hammers. The one-piece steel hammer has become very popular with many workers. The handles are usually of tubular steel with a leather or plastic grip. Some workers feel that fiberglass handles are superior to either steel or wooden handles.

The **curved-claw hammer** (fig. 1) gets its name from the fact that the claw is forged in a curved sweep. This provides easy pulling action when nails are being removed. The curved-claw hammer is by far the most popular style of hammer for driving nails. It ranges in size from 7 to 20 ounces. The 16-ounce size is usually the most popular. It is available with either a round or an octagonal head.

Some steel-claw hammers are called **ripping hammers** since they are widely used for ripping wood apart. This steel claw is only slightly curved. It slips easily under the edges of boards for prying.

The **ball-peen hammer**, or **machinist's hammer**, has a head especially designed for driving and forming metals (fig. 2). The peen is rounded, or ball-shaped, for flattening the ends of rivets, while the face is slightly rounded and is used for driving chisels, center punches, and other metalworking tools. Ball-peen hammers come in size from 4 ounces up to 2 1/2 pounds.

Soft hammers and **mallets** (fig. 3) are used to pound or drive objects or perform other operations where a steel hammer would mar or possibly break the work. The materials used for the soft faces are plastic, copper, lead, rawhide, wood, brass, and rubber.

The **hand-drilling hammer** is used where a heavy hammer is needed. It is designed for heavy-duty work with a star drill or a cold chisel. The handle is short, and the size of the hammer ranges from 2 to 4 pounds. If you do much drilling with a star drill (masonry drill bit), you should get this hammer.

Sledgehammers vary in weight from 2 to 20 pounds. They are used quite often

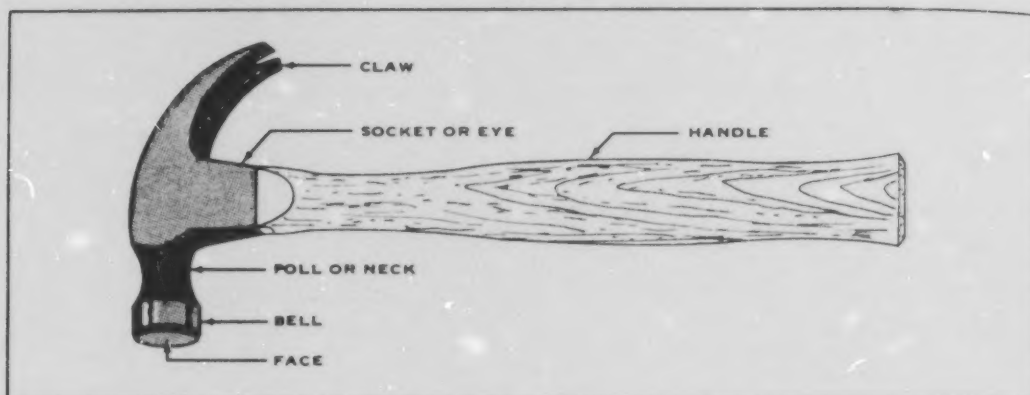


Fig. 1. Wooden handle claw hammer



Fig. 2. Ball-peen hammer

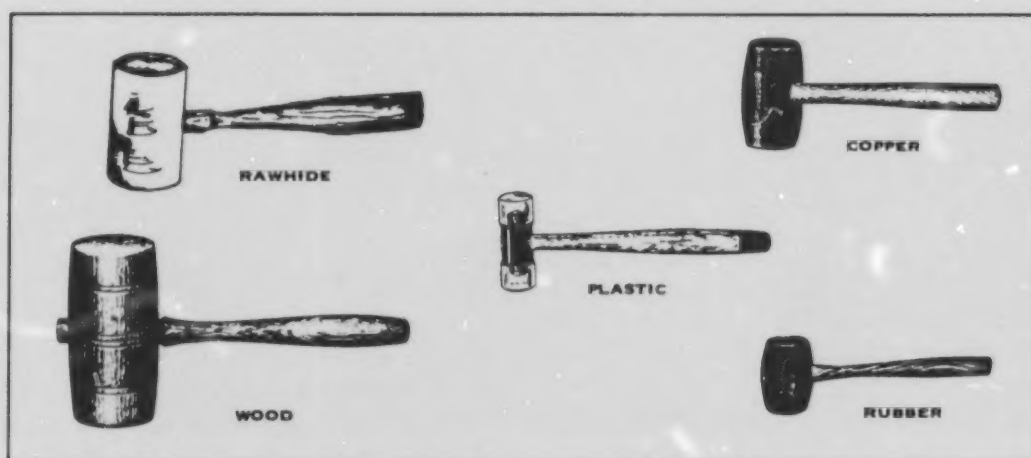


Fig. 3. Mallets

when heavy machinery must be pounded because large parts have "frozen" after many years of use. Sharp, heavy blows may be necessary to loosen or move these parts.

Although they are not pounding tools, long, heavy steel pry bars must often be used to move equipment into a certain position. These pry bars may be several feet long and an inch or more in diameter. Sledgehammers may be used to pound the end of the pry bar under some conditions. Always place wood against metal parts that must be pounded to prevent marring or breaking of the parts.

Using Hammers. Most people think that hammers are safe tools to use because they have no cutting edges. However, you should follow certain procedures to prevent accidents or mutilation of the materials where hammering is necessary. Hold the hammer near the outer end of the handle. When nailing, hold the nail directly below its head with your left hand (if you are right-handed). Strike a light blow to establish the aim and also to begin to set the nail. Strike a square blow to keep from bending the nail or denting the wood. If the nail begins to bend, remove it and replace it with a new nail. Keep the hammer face and the nailhead clean to prevent a blow from glancing off the nailhead. Do not strike the nail with the cheek (side) of the hammer. This is the weakest part, and the hammer claws may also mar the wood.

When a nail is driven at a right angle to the surface of a piece of wood, the operation is called **face nailing**. Avoid driving the nail too close to edges or ends. This causes splitting. Splitting can be partly eliminated by staggering the nails or dulling the point of the nail.

Toenailing is a procedure done quite often on a frame work structure (fig. 4). The nails are driven at an angle to the edge or face of the wood. Toenailing is necessary when it is impossible to nail from the face.

Edge nailing is used to fasten flooring that has tongues and grooves that slip together on edges and ends of wood. The nail is driven into the tongued edge to draw it into the groove at the same time that the material is fastened to a joist or sill.

When **removing nails**, place the claw of the hammer under the nailhead. Then pull the end of the handle until the handle is nearly vertical. If the nail is short, it will

have been removed at this stage. If the nail is longer, place a block of wood under the hammerhead. This increases leverage so that the nail is removed vertically. Without the block, the hammer handle may break, or the wood may be marred by the hammer or nail.

Ripping Bars

A ripping bar is used to pull wood structures apart. It is built to provide the necessary leverage to pull large nails that cannot be removed with a regular nail hammer.

You can find several types of ripping bars. The most common is the **gooseneck bar**, sometimes called a **wrecking bar** (fig. 5). It has two claws like the curved claws of a standard hammer. It is an efficient nail puller. The chisel-pointed end of a gooseneck bar can be forced into cracks to pry and rip in the same manner as a ripping chisel.

Screwdrivers

The screwdriver drives and removes screws. It is probably the most misused of all hand tools. It is variously used as a chisel, a punch, a pry bar, a tire tool, and an ice pick. Some people even use screwdrivers to mix paint. Screwdrivers are classified in two main groups, the standard or the Phillips. The size of a screwdriver is usually determined by the length of the shank and is usually specified as stubby, 2 1/2-inch, 3-inch, 4-inch, 5-inch, 6-inch, 8-inch, 10-inch, and 12-inch.

Parts of a Screwdriver. Although many different types of screwdrivers are designed to fit special types of job, the typical screwdriver looks like the one in figure 6. The handles of screwdrivers may be smooth, but they are usually fluted to give a better grip. They may be made of wood, hard rubber, metal, or plastic. Most, however, are now made of plastic that is strong, attractive, and a good insulator.

The **ferrule** is the metal band or sleeve surrounding the lower portion of a wooden handle. It helps anchor the shank in the handle and also keeps the wood from splitting.

The **shank** is the long steel portion that extends from the handle. It is usually of

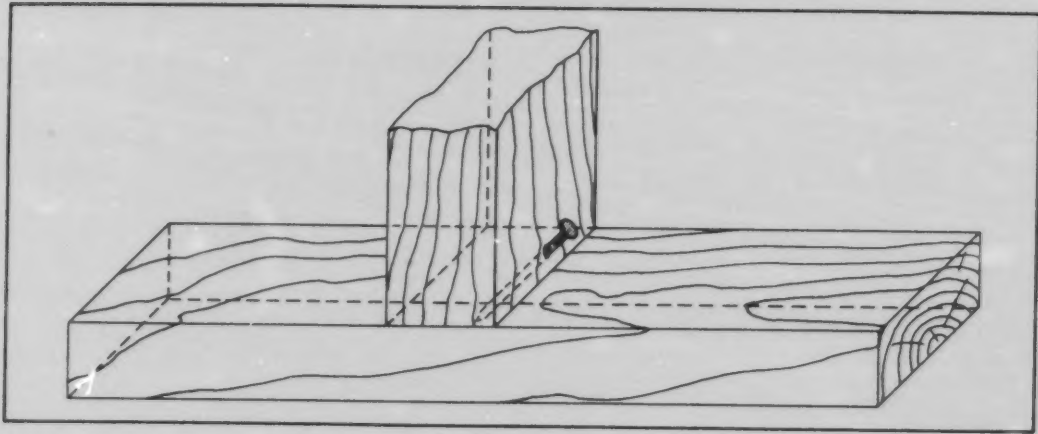


Fig. 4. Toenailing



Fig. 5. Gooseneck bar



Fig. 6. Typical screwdriver



Fig. 7. Spiral-ratchet screwdriver

round stock in small screwdrivers. The shanks of heavy-duty screwdrivers are often square. The portion of the shank that fits into the handle may be secured by several methods. It may be held by a rivet through the ferrule and shank, or the shank may be formed and pressed into the handle. Sometimes the handle is molded around the shank under heat and high pressure.

The screwdriver **tip** is that portion of the blade that engages the screwhead. The **blade** may have a flange tip or a parallel tip.

Types of Screwdrivers. The **all-purpose** screwdriver is usually about 6 to 8 inches long, with a slim steel shank and a wooden or plastic handle. It is designed to withstand considerable twisting force. After a shank is bent, it is almost impossible to straighten it.

The **heavy-duty** screwdriver is designed for heavy work and usually has a square shank. This screwdriver is particularly useful when doing heavy work. The square shank allows the use of a wrench for added turning force.

The **stubby** screwdriver has a shank about 3 inches long, which makes it a handy tool in close or cramped places.

The **spiral-ratchet** screwdriver (fig. 7) is operated by a reciprocating motion of the handle. This means that when the handle is pushed down, the bit turns. The ratchet is located in the ferrule. It has a button that can be set to turn the screwdriver left or right. An advantage of the spiral-ratchet screwdriver, other than speed, is that interchangeable blades and bits can be used.

The **Phillips** screwdriver is used on screws found in all types of sheet metal work. Instead of the conventional blade, it has four flutes shaped in a cross (+) to fit the recessed head of the Phillips screw. This screwdriver offers a more positive drive and prevents marring of the screwhead. The Phillips screwdriver is classified by the size of the blade grooves. The No. 0 screwdriver is the smallest, and the No. 4 is the largest.

Care and Maintenance

Sharpening. At times screwdrivers become dull and the corners become rounded. To sharpen, grind the tips at 90° to the shank until the corners are square. Occasionally

you may need to touch up the tips of Phillips screwdrivers with a triangular file so that the flutes fit the screwheads better. If the faces of hammers become rounded, they should also be ground flat.

General Care. Always keep the head of a hammer clean. A slick hammerhead may slip off the nail and either damage the material or injure the user. It may also cause nails to bend.

If a hammer handle becomes dried out and shrinks (which could allow the head to fly off the handle), immerse the tool in water, and drive the wedge further into the end of the handle. The wedge is a small, tapered wooden or metal device that spreads the wood of the handle against the head.

Store hammers in toolboxes or hung on a wall. Use care when using all hammers. Keep your fingers away from the pounding area.

Screwdrivers should be arranged by size and kept in a particular place. Use the correct size for the job so that you won't tear the edge of the screw and leave burrs that can cause serious cuts. Do not use screwdrivers for prying, stirring paint, or chiseling. A bent screwdriver is inaccurate and dangerous.

Exercise

1. What is the most popular size of a curved-claw hammer?
2. For what type of work is the hand-drilling hammer designed?
3. When nailing, where should you hold the hammer handle?
4. What is the weakest part of the hammer?
5. What does **toenailing** mean?
6. What is the purpose of a ripping bar?
7. What are the two main groups of screwdrivers?
8. What is the **ferrule** on a screwdriver?
9. What type of shank is found on a good-quality, heavy-duty screwdriver?
10. How do you make the tip of the spiral-ratchet screwdriver turn?
11. What are the advantages of a Phillips screwdriver?
12. What should you do if a hammer handle has dried out and becomes loose?

C-5

Pliers and Wrenches

Objectives: After completing this assignment, you will be able to—

1. describe the various types of pliers and their uses;
 2. discuss types of wrenches and how they are used; and
 3. give precautions to take when using pliers and wrenches.
-

Pliers

Pliers cause the most damage of all hand tools. Improperly used, they may mar work, damage it beyond repair, or injure the worker. They are designed for no other purpose than holding and bending. To prevent undue wear and rust, pliers should be kept clean and oiled on the joint pin.

Pliers are sized by their overall length. The worker determines what size of pliers to use by the type of work to be done. The heavier the work, the larger the pliers should be.

Pliers are classified by the shapes of their noses and by the functions they perform. Although there are dozens of types of pliers, only those in common use are described in this assignment.

Combination Slip-Joint Pliers. These pliers (fig. 1) are by far the most common type. They are valuable utility tools if they are used correctly. The slip joint permits the jaws to be opened to a wider position for gripping larger diameters. Such pliers are available in 5-, 6-, 8-, and 10-inch sizes. Most combination pliers have shearing jaws for cutting wire and copper pins. However, some are thin-nosed for use in confined places. Some have offset jaws.

Diagonal Pliers. Diagonal pliers (fig. 2) are made with the cutting jaws at about a 15° angle to the handles. The worker uses them to cut various diameters of regular

and electrical wire. Never use these pliers to hold an object or to cut wire that is too large for them.

Longnose Pliers. Longnose pliers (fig. 3) are used mainly in confined areas where the long, slender jaws can reach into the work. They are sometimes used during soldering. They should not be used for heavy-duty work.

Vise-Grip Pliers. Vise-Grip pliers (fig. 4) have powerful, adjustable jaws that may be locked tightly on the work. They may be used like a small vise to hold small work and sheet metal parts in place during drilling or soldering. They are also useful for a person working alone or for holding nuts or bolt heads that have already been marred.

Wrenches

Wrenches come in many types, sizes, and shapes. They are classified as either non-adjustable or adjustable.

Nonadjustable Wrenches. The open-end wrench is the oldest of this type. The opening consists of two jaws that fit over the nut or bolt head (fig. 5). Usually, each end of the wrench has an opening, but some types have only one. The openings at each end are of different sizes, usually one size apart. One open-end wrench is actually two wrenches of different sizes. A set of ten or twelve of these wrenches gives a combina-



Fig. 1. Combination slip-joint pliers



Fig. 2. Diagonal pliers



Fig. 3. Longnose pliers

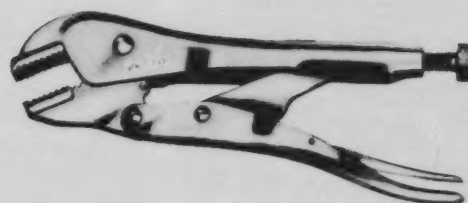


Fig. 4. Vise-grip pliers

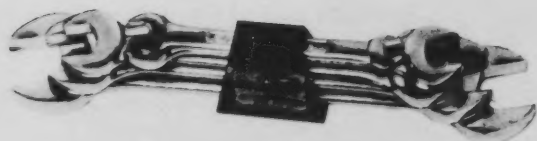


Fig. 5. Open-end wrenches

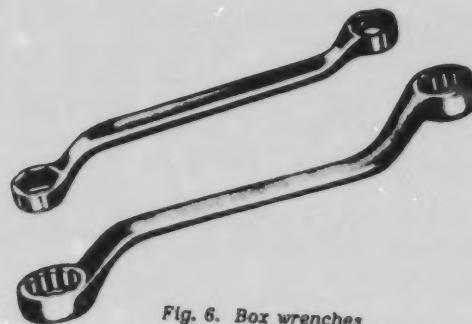


Fig. 6. Box wrenches

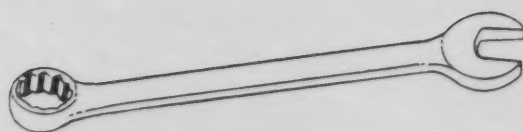


Fig. 7. Combination wrench (half-and-half)

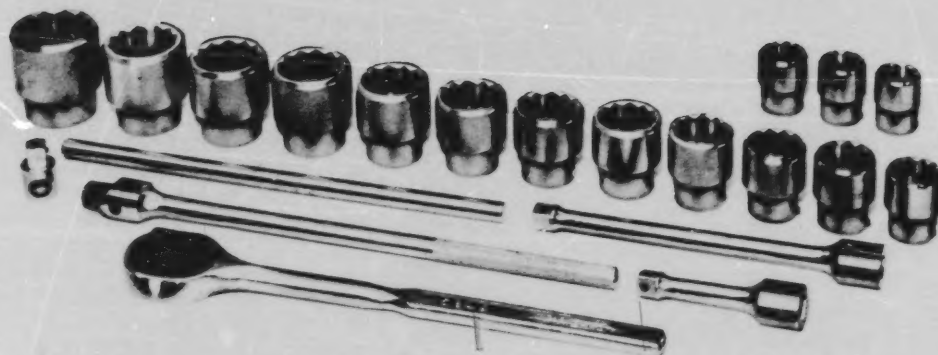


Fig. 8. Socket wrenches

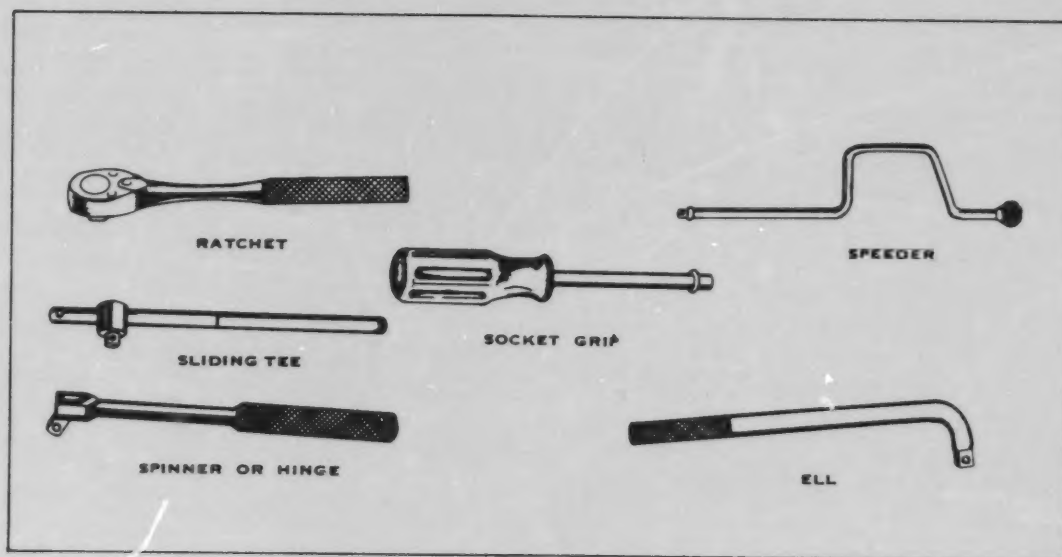


Fig. 9. Types of socket handles



Fig. 10. Adjustable wrench

tion of sizes to fit most sizes of nuts. To designate an open-end wrench, you should identify both opening sizes.

The jaws of open-end wrenches are parallel and are usually set at a 150° angle to the handle. This enables the user to tighten a hex nut with a minimum of swing. If the wrench had straight jaws, it would have to be swung at least 60° to engage a new set of flats (sides), since the angle between the flats is 60° . However, if the jaws are at a 150° angle to the handle, the amount of swing required is halved. By turning the wrench over, the line of the jaws is changed 30° without changing the relative position of the handle. By turning the wrench over and completing another swing, a hex nut can be tightened.

The opening between the jaws is machined slightly oversize (usually 0.01 inch) to allow it to slide over the nut. The thickness of open-end wrenches usually varies with the strength of the metal from which they are made. Although the length of open-end wrenches has not been standardized, most manufacturers make the length about twelve times the opening size. You will notice that small-sized wrenches are usually shorter than large-sized wrenches. The larger nut is harder to turn, so more leverage must be applied.

Box wrenches, or **box-end wrenches**, completely surround or box in the nut (fig. 6). They normally have 12 points or notches inside, which allow the wrench to be swung in an arc as small as 30° . They engage the nut more securely than an open-end wrench. Thus, they are more useful in breaking a tight nut or tightening up a nut the last few turns. You must, however, lift the wrench from the nut and replace it at a new angle for each swing. This process is a little slower than using an open-end wrench.

To correct this problem, some wrenches come with one open end and one box end (fig. 7). The box end is used for breaking or tightening a nut, and the open end is used for moving it up or down the threads. The two ends of this type of wrench are the same size. They are called **combination wrenches** or **half-and-half wrenches**. Most box wrenches have handles that are not in line with the head, to allow room for the fingers on the underside of the wrench. These offset handles are angled from 15° to 45° from the box end.

Socket wrenches are the fastest and easiest type of wrench to use (fig. 8). They have all the best features of both open-end and box wrenches and are adaptable for use with a wide assortment of handles. The socket wrench, like the box wrench, has 6, 8, or 12 points inside one end for engaging the nut. Opposite the box end is a square hole, or sometimes a hex hole, for receiving the drive of the handle. Common handles for sockets (fig. 9) are the ratchet, sliding tee, speeder, spinner (hinge handle), socket grip, ell, and torque (tension).

The ratchet handle makes it possible for a nut to be tightened or loosened without removing the handle with a small shifting lug. The ratchet handle may be used in close quarters where the angle of swing is even less than 30° . The angle of swing depends on the number of teeth or points on the ratchet.

The size of the drive for a socket set usually indicates both the range and size of the sockets. A 1/4-inch drive is usually the smallest and is used with lightweight sockets that range from 3/8 to 1/2 inch. A 3/8-inch drive works with heavier sockets that range from 1/4 inch to 3/4 inch. A 1/2-inch drive is used with the standard set of sockets ranging from 3/8 inch to 1 1/8 inches.

A torque wrench measures the amount of torque or force, measured in foot-pounds or inch-pounds, that is applied to the bolt or nut. The amount of force applied to the handle is unrelated to hand placement, length of handle, or weight of handle. Torqueing specs (specifications), or the amount of force needed, are based on bolt strength, preload tension, compressibility of material, thread strength, and so on, and therefore **must** be measured at the center of the bolt.

Adjustable Wrenches. The adjustable wrench (fig. 10) has some of the desirable features of open-end wrenches, plus provisions for adjusting the opening between the jaws. It is also known by the trade name **Crescent wrench**. Although useful in turning odd-size nuts and bolts, it should not be used if an open-end or box wrench of the proper size is available. The jaws engage the nut rather securely, but they require frequent readjustment to maintain the proper fit. These wrenches are sized according to the overall length, which ranges from 2 inches to 24 inches.

Maximum jaw openings range from 1/8 inch to about 2 1/2 inches.

Using a Wrench. The wrench must fit the nut or bolt head. A wrench is made slightly oversize to enable it to fit easily, but not loosely, over the nut. Much more strain is put on the jaws of a loose-fitting wrench than on one that fits properly.

Hex or square heads may become so battered through rough usage that the proper wrench will not fit. You may be tempted to use a larger size wrench, but this may slip once the battered edge of the nut gives way, causing skinned or bruised knuckles. If the flat of a nut is battered, touch it up with a file so that the proper size wrench will fit.

If you have a choice, pull the wrench rather than push it. If a nut breaks loose suddenly while you are pushing with a lot of force, you may strike your hand against an object before you can stop it. If the wrench must be pushed, it may be done fairly safely in short, quick pushes. Never hammer a wrench with a hard, heavy object.

Exercise

1. What is the advantage of combination slip-joint pliers?
2. How are diagonal pliers used?
3. How are wrenches classified?
4. What is the usual jaw angle of open-end wrenches to the handle?
5. How many points or notches are usually found inside a box wrench?
6. What are wrenches with one open end and one box end called?
7. What is the fastest and easiest type of wrench to use?
8. What does the angle of swing of a ratchet handle depend on?
9. What wrench should not be used if an open-end or box wrench of the proper size is available?
10. What should you do if the flat of a nut is battered?
11. What is the advantage of the long, slender jaws on longnose pliers?
12. What does the length of open-end wrenches usually depend on?

C-6

Vises and Clamps

Objectives: After completing this assignment, you will be able to—

1. identify woodworking and machinist's vises and their uses;
 2. discuss various glue clamps and how they are used; and
 3. describe appropriate care and maintenance of vises and clamps.
-

Vises

Woodworking Vises. These vises are mainly used for holding materials for planing, sawing, chiseling, and boring. They are attached to the left front corner of a woodworking bench or table. The top edges of their jaws line up with the surface of the table. This makes it possible to saw the material without cutting the workbench. The jaws are large, flat, rectangular, and parallel to each other (see fig. 1). As a general rule, they are made in two sizes. The smaller size is 4 inches deep and 7 inches wide, and opens up for material 9 inches wide. The larger size is 4 inches deep and 10 inches wide, and will take material up to 12 inches wide.

They are built in two designs, continuous-screw and rapid-acting. The **continuous-screw vise** has a long, threaded clamping screw, which is operated by the handle. It must be screwed in or out the desired distance.

The **rapid-acting vise** is built so that the handle can be turned three-fourths of a turn to clamp the work. When turned back to the starting position, the jaws may be slid rapidly to the approximate size of the piece of work to be clamped. When given a partial turn, the clamping operation is complete. The vise body and front jaw are usually made of malleable cast iron. It will not stand blows of any great force.

Machinist's Vises. The machinist's vise (fig. 2) is normally used for holding metals, but it can also be used for wood. It is usually fastened solidly to a strong base. Machinist's vises are sized by the width of the jaws and the full opening between the jaws. The swivel vise shown in figure 2 is attached firmly to the bench or mounting. The body of the vise turns on a central bolt or pin. The locking lever at the side of the vise locks it into position. You may loosen this lever, swivel the vise to any desired position, and then relock it. Such a vise is very adaptable, allowing irregular work to be positioned so that parts can be reached easily. This feature is an advantage over the stationary type of vise.

Clamps

Clamps are tools used to hold objects together while work is done on them. Clamps are unlike vises in that they may be taken about and used anywhere in any position with little difficulty. They clamp pieces of work to the drill-press table for drilling or hold parts together for soldering, riveting, or gluing. The most common clamps are C-clamps, hand-screw clamps, bar clamps, and spring clamps.

C-Clamps. The C-clamp (fig. 3) has a heavy iron or steel body made in the shape of a C, with a flat pad on one clamping surface and a screw pad on the other.

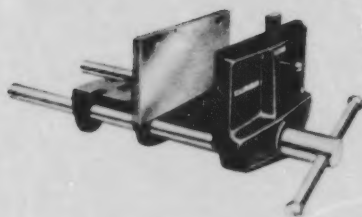


Fig. 1. Woodworking vise

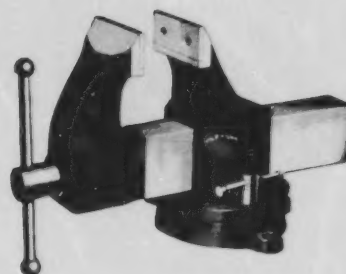


Fig. 2. Machinist's vise



Fig. 3. C-clamp

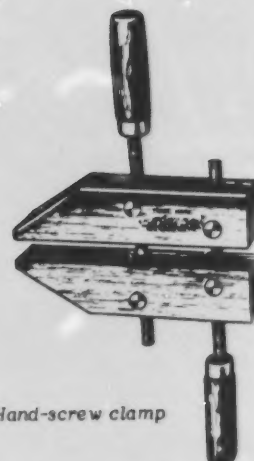


Fig. 4. Hand-screw clamp



Fig. 5. Steel bar clamp



Fig. 6. Pipe bar clamp



Fig. 7. Spring clamp

Screw handles vary and are available with wing nuts, bar-type handles, or square heads that can be tightened with a wrench. C-clamps are widely used for both woodworking and metalworking jobs. They come in light-duty, medium-duty, and heavy-duty weights.

Hand-Screw Clamps. The hand-screw clamp (fig. 4) is used mainly for gluing wooden parts together. The adjusting screws are threaded with both right- and left-hand threads on the same screw. This allows the clamp to be adjusted rapidly by holding it by the handles and spinning it.

When fastening two or more pieces of material together, you will need to adjust the clamps so that the front ends of the jaws remain slightly open. Tighten the front screw down on the materials, which causes the rear of the jaws to tighten against the object. Then tighten the rear screw, bringing the jaws parallel against the object. This produces an even pressure the length of the hand-screw jaws. Sometimes irregular work can be held between the jaws of the hand-screw clamp. For this type of job, you would place the hand-screw clamp in a vise. This provides a handy method of holding irregular work in awkward positions.

Bar Clamps. The bar clamp is designed for assembling and gluing doors and large pieces of wood. Bar clamps are of the solid steel bar type and the pipe body type.

The **steel bar clamp** has a strong steel bar with notches in either its side or edge (fig. 5). An adjustable jaw slides along this bar and has a locking device in the shape of a lever. When the jaw is adjusted to about the right length, you can release a spring with your finger, and the lever will drop into the nearest notch. A crank screw applies the clamping pressure at the head of the clamp.

The clamp shown in figure 5 has holes along the bar. A pin is inserted in the hole nearest the desired length. The crank screw is only adjustable within a range of 6 inches. It is attached to a sliding front jaw. The wider adjustments are made with the sliding jaw mentioned previously. This style of bar clamp comes in lengths of 2, 3, 4, 5, and 6 feet.

The **pipe bar clamp** has the same features as the steel bar clamp except that a 1/2-inch or 3/4-inch black iron pipe is used for the bar (fig. 6). The sliding jaw has a

lever clamping device that locks at any position along the pipe. One advantage of the pipe clamp is that different lengths of pipe can be used to hold various widths of lumber or objects during gluing or assembly processes.

When you are using either clamp for gluing wooden panels together, place clamps on alternate sides of the work. This prevents the materials from cupping, warping, or flipping out of the clamps. Sometimes you must use hand-screw clamps to clamp the flat stock to the bars of the bar clamp.

Spring Clamps. The spring clamp (fig. 7) is a valuable tool for holding parts together temporarily for light gluing and cementing jobs. It is made like a giant spring clothespin, and several can be applied around the work.

Care and Maintenance

Keep vises securely fastened to the workbench, and screwed shut when not in use. Fasten jaw protectors to the vises, or place wood scraps between the jaws and the work to protect the material from scarring.

Clamps should be kept in a rack, out of the worker's way. If you hang bar clamps on the wall, be sure they are fastened securely. The weight of a falling clamp could cause serious injury. Remove any glue from the clamps, and occasionally lubricate the screws.

Exercise

1. Where are woodworking vises attached to a bench or table?
2. What are the two types of woodworking vises?
3. What type of vise may be swiveled to various positions?
4. How are machinist's vises sized?
5. What are four types of common clamps?
6. How is a C-clamp constructed?
7. How are the adjusting screws on a hand-screw clamp threaded?
8. For what purpose is the bar clamp designed?
9. What is the chief advantage of a pipe bar clamp?
10. How are spring clamps made?
11. What should you use between vise jaws and the work?
12. Where should you store clamps?

C-7

Threading Tools and Hammers

Objectives: After completing this assignment, you will be able to—

1. discuss the various types and sizes of threading taps and wrenches;
 2. explain the procedures to use when tapping;
 3. discuss threading dies and how they are used; and
 4. discuss reamers and how they are used.
-

Taps

Types and Sizes. Taps are screwlike tools that have threads like a bolt and usually three or four flutes, which are cut across the threads (fig. 1). Taps are used to cut threads on the inside of a hole. This might be the inside of a nut or a hole drilled in a plate of metal that is to receive a threaded stud. Cutting flutes on the taps creates cutting edges and provides spaces for the removal of chips (fig. 2). One end of the tap is square so that the tap may be turned with a tap wrench. Taps are sometimes called hand taps and are constructed from high-speed or carbon steel. They are available three in a set—taper tap, plug tap, and bottoming tap (see fig. 1).

The most common tap, the **plug tap**, has the threaded end tapered for a distance of four or five threads to make it easier to start the tap in the hole. Plug taps are used for tapping through a hole and for all-around purposes.

When considerably more taper is required, the **taper tap** is used. The threaded end is tapered over half its length, making it the ideal tool for starting the threads in a blind hole.

The **bottoming tap**, which has full threads with very little taper, is used for finishing threads full size after they have

been started with a taper tap or plug tap. Blind holes (those that do not go through the metal) are tapped with this type of tool.

When a bolt must be turned clockwise to screw it into a nut, it has right-hand threads. The bolt that is turned counter-clockwise into the nut has left-hand threads. As you will probably encounter both types, you will need taps for cutting both right-hand and left-hand threads. The letter L stamped on the shank indicates that the tap cuts left-hand threads. If no letter is stamped on the shank, the tap cuts right-hand threads.

Taps are available in the same sizes as bolts and screws. The outside diameter of the tap and the number of threads per inch are stamped on the shank of the tap.

Tap Wrenches. Two types of wrenches are used for turning the taps: the T-handle tap wrench and the adjustable hand tap wrench. The **T-handle wrench** has an ordinary T handle with a chuck for holding the tap (fig. 3). The **hand tap wrench** has an adjustable opening between the two handles to hold different sizes of taps (fig. 4). If an obstruction prevents the use of either of these wrenches, a regular open-end wrench of the proper size is a suitable substitute.

Tap Drills. Drilling the proper size hole that is to be tapped for a certain screw is of utmost importance. If the tap and the hole

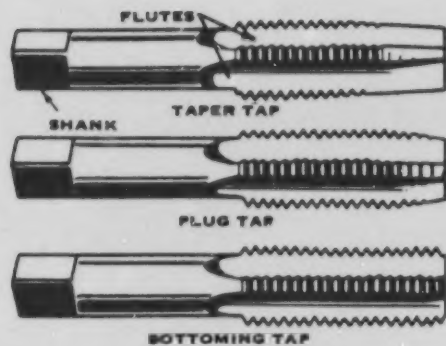


Fig. 1. Taps

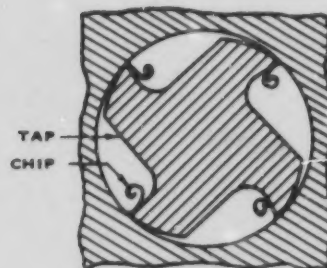


Fig. 2. Tap cutting

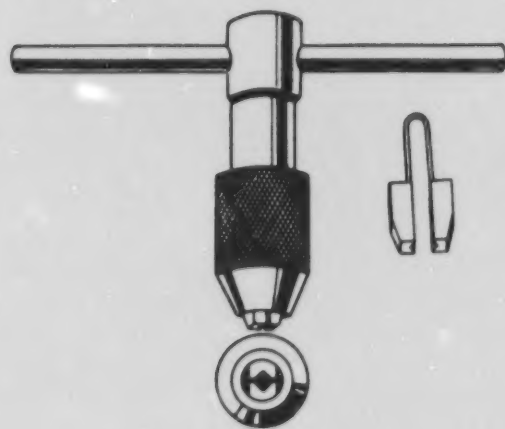


Fig. 3. T-handle tap wrench



Fig. 4. Adjustable hand tap wrench

were of the same size, no threads would cut. If the hole were too small, the tap could not be made to enter it. The hole must be smaller than the tap by a recommended amount in order to leave the proper amount of metal from which correctly formed threads can be cut. This amount is about 75 percent of the depth of the thread. Since the depth of a thread is also about 75 percent of the pitch, the pitch may be subtracted from the tap size to determine the drill size. For example, if the tap size is $3/8 \times 16$, the drill size is $3/8$ minus $1/16$, or $5/16$ inch.

This method, which is only approximate, is difficult to use with numbered taps and drills. It is wise to consult a tap and drill table for the recommended drill size for each tap size. Table 1 gives the size of tap, threads per inch, and tap drill for both the American National Fine Threads and the American National Coarse Threads.

In tapping holes for cap screws, where the screw passes through a clearance in one piece of work and screws into another, you must consider the hole for the body of the screw. The body drill size, then, is the size hole that will allow the full length of the screw to enter the hole with a proper amount of clearance. It is usually determined by adding $1/16$ inch to the tap size.

Tapping. After you have drilled the hole in the material to the proper size, you are ready to **tap**, or **thread**. Clamp the work in a vise with the hole upright. Fasten the tap securely in the tap wrench. Use the taper tap first, and hold the wrench near the center with the thumb and fingers of your right hand.

After squaring the tap with the hole, engage the wrench, and slowly turn it one revolution, which is usually enough to allow you to let go with your hand. By sighting from various angles, you can check the tool for squareness. If it appears to be square, turn it another revolution and check again for squareness. If the tap is not square, back it out and start again. After the tap has been started squarely, you should turn the wrench with both hands until the last threads have entered the hole. Both hands must apply the same amount of force to the handles, or the tap will lean to one side and may even break off in the hole. Breakage may be reduced by using three taps during the operation.

Use the taper tap until it is hard to turn. Then, back it out of the hole and use the plug tap until it also becomes hard to turn. Then use the bottoming tap. If it becomes hard to turn before the threading operation is finished, use the taper tap again. The use of the three taps may be repeated until the hole has been threaded.

In tapping steel, the tap should be backed off (turned back) a fraction of each forward cut to break the chip and allow the lubricating oil to cover the cutting edges. If the metal is relatively soft, no backing off is necessary. No downward pressure is needed to make the tap cut. In fact, a better thread will result without it.

Lubricating Oils. Proper lubrication, a crucial factor in all metalcutting operations, is especially important in tapping. Because the first few teeth of the tap cut deeply into the metal, making it difficult for lubricants to reach them, a lubricant with high penetrating properties is required.

In tapping steel and bronze, supply the hole with enough oil to make the removal of chips easier and to prevent excessive heat. Although you would use light mineral oil for tapping cast iron, you may tap blind holes in cast iron while using a mixture of oil and white lead. The white lead tends to hold the chips in the flutes and prevents them from falling into the blind hole. Table 2 lists the lubricating oils to use while tapping various types of materials.

Broken Taps. There are several causes of broken taps. A lack of oil may cause the tap to stick and break. A warped or lopsided tap may stick and crack. The hole for the tap may be too small. Or, the large amount of twisting force may be applied out of vertical. Occasionally, failure to back the tap out will cause the chips to clog in the flutes, and the extra force applied to break them loose will snap the tap.

A broken tap is usually removed with a **tap extractor**. A hole is drilled into the center of the broken tap. Then, the tap extractor is pushed into the hole and turned counterclockwise, and the tap is screwed out. The procedure is similar to the way a corkscrew works.

Dies

A **threading die** is a round or square block with a hole in the center and flutes and

TABLE 1
TAP DRILL SIZES

<i>American National Fine (NF)</i>			<i>American National Coarse (NC)</i>		
<i>Size of Tap</i>	<i>Threads per Inch</i>	<i>Tap Drill</i>	<i>Size of Tap</i>	<i>Threads per Inch</i>	<i>Tap Drill</i>
# 4	48	43	# 4	40	43
# 6	44	37	# 5	40	38
# 8	40	33	# 6	32	36
#10	36	29	# 8	32	29
#10	32	21	#10	24	25
#12	28	14	#12	24	16
1/4	28	3	1/4	20	7
5/16	24	I	5/16	18	F
3/8	24	Q	3/8	16	5/16
7/16	20	25/64	7/16	14	U
1/2	20	29/64	1/2	13	27/64
9/16	18	33/64	9/16	12	31/64
5/8	18	37/64	5/8	11	17/32
3/4	16	11/16	3/4	10	21/32
7/8	14	13/16	7/8	9	49/64
1	14	15/16	1	8	7/8

TABLE 2
RECOMMENDED LUBRICANTS FOR TAPPING

<i>Metal</i>	<i>Lubricant</i>
Alloy steel, low-carbon steel	Sulphur base oil, mineral lard oil
Cast brass, bronze	Soluble oil or dry
Cast iron	Light mineral oil
Copper, brass	Soluble oil or lard
Aluminum	Soluble or mineral lard oil

threads that are used to cut threads on the outside of metal rods or bolts. This device is made of hardened steel and comes in three styles. The **round, adjustable split die** (fig. 5) is the most commonly used die. Because it is adjustable, it may be set for various sizes. There is also a **two-piece die**, made in two matching halves, that is adjustable. The **solid square die** is made in one piece and does not allow for adjustment. Taps and dies may be purchased in a set, called a **screw plate**, containing various sizes of each.

You may also purchase dies with either left-hand or right-hand cutting abilities. As with taps, the dies stamped with the letter **L** are used for cutting left-hand threads, and no stamp indicates that they are for cutting right-hand threads.

The die will have the size of the threading die and the number of threads per inch stamped on it. If the die is stamped with 1/4-28 (NF), this means that the die will cut a thread with a major diameter of 1/4", and it will have 28 threads per inch. The sizes of these screw threads are given in table 1 and are also the sizes of the threading dies. A **collet** is the holder into which the threading dies fit. Under the die is a ring, called a **guide**, which fits around the material to be threaded and is used to guide the die so that it will go on the work squarely.

Setting and Threading

The round, adjustable split die must be set by turning the setscrew with a screwdriver. When the proper adjustment is made, you can start threading.

The first step in threading is to file or grind a chamfer on the end of the rod to be threaded. This allows the die to start easier. The die must be right side up in the die stock (fig. 6). The starting side can be distinguished by its slightly larger opening and less clearly defined teeth. The die should be square with the work. When starting the die, it is best to hold the stock near the head, giving the tool one or more turns until the thread is just started. Proper alignment may be determined by sight.

As in the case of tapping, you should back up the die a short distance after each half revolution. You will need to apply oil during the threading operation. After the

thread is cut, the stock may be spun off, but it should not be allowed to spin on the threads after becoming disengaged from them.

Threading Pipe

Pipe dies are used to cut threads on pipes (fig. 7). The dies are held in the die stock. The primary differences between pipe dies and other dies is that pipe dies have threads that taper at 3/4 inch per foot. These dies are marked with the size of pipe on which they are to cut threads. Therefore, 3/4-inch pipe dies will cut threads on 3/4-inch pipe. As with other dies, adjustable pipe dies may be purchased.

The drill used to drill a hole before it can be tapped is called a **tap drill**. As shown in table 3, a 3/4-inch pipe tap will need a tap drill of 15/16 inch.

A **pipe reamer** (fig. 8) must be used to taper a drilled hole that is to be tapped. This allows the hole to be more the shape of the pipe tap. Tapping is then much easier and the wear on the tap is reduced.

The **pipe tap** (fig. 9) is used to cut the threads on the inside of a pipe or pipe fitting. The tap is tapered and is similar to other taps discussed. The tapping procedure is the same as for other taps discussed.

Reamers

Reamers are tools that enlarge and smooth drilled holes. They are particularly valuable for precision work. Because it is almost impossible to drill a perfectly round hole to exact size with a twist drill, holes that are to conform to precise measurements are usually drilled slightly undersize and reamed to specifications.

Construction. The cutting edges on reamers are formed by several flutes along the body. Between the flutes are raised portions of metal called **lands**, or **teeth**, that cut when the tool is turned in a right-hand direction.

The flutes are either straight or spiral (helical) (fig. 10). Reamers cut from one piece of steel are classified as **solid**. Those with adjustable lands are classified as **expansion** reamers. The adjustment consists of an increase or decrease of a few thousandths of an inch in the diameter of the reamer.

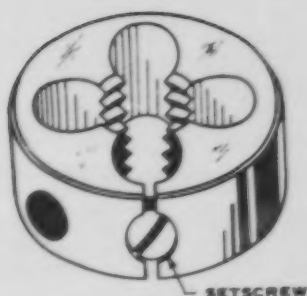


Fig. 5. Round, adjustable, split die



Fig. 6. Die stock

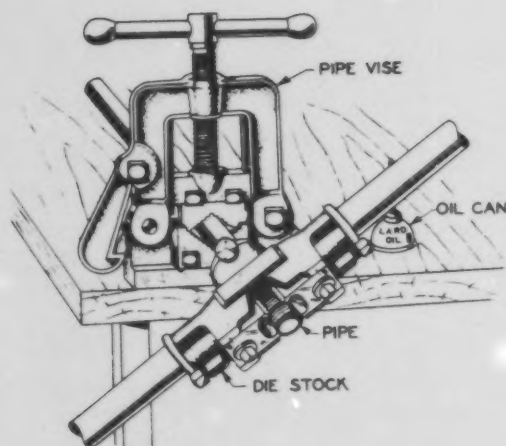


Fig. 7. Pipe die

TABLE 3
DIMENSIONS OF PIPES

Pipe Diameters			Threads per Inch	Tap Drill Size
Nominal Size	Actual Inside	Actual Outside		
1/8	0.270	0.405	27	11/32
1/4	0.364	0.540	18	7/16
3/8	0.494	0.675	18	19/32
1/2	0.623	0.840	14	23/32
3/4	0.824	1.050	14	15/16
1	1.048	1.315	11 1/2	15/32
1 1/4	1.380	1.660	11 1/2	1 1/2
1 1/2	1.610	1.900	11 1/2	1 23/32
2	2.067	2.375	11 1/2	2 3/16
2 1/2	2.468	2.875	8	2 5/8



Fig. 8. Pipe reamer

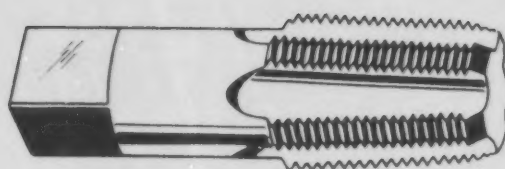


Fig. 9. Pipe tap

STRAIGHT FLUTED



SPIRAL FLUTED



Fig. 10. Types of flutes on reamers



Fig. 11. Burring reamer, straight fluted

The shanks of reamers are available in three types: straight, taper, and bit stock. **Straight** shanks are square for receiving a tap wrench for turning. **Taper** shanks usually have Morse tapers on the gripping end. **Bit stock** shanks are used with a carpenter's brace.

Types of Reamers and Their Uses. Generally, reamers are classified in two groups: (1) hand reamers and (2) chucking, or machine, reamers. **Hand reamers** cut on the outside edges of the reamer, while **chucking reamers** cut on the beveled end, much as a drill cuts.

Hand reamers, either solid or expanding, are turned by hand with tap wrenches. The starting end is slightly tapered, and the flutes may be straight or spiral. Chucking reamers, with tapered shanks and slightly tapered starting ends, are used in drill presses and lathes. **Taper-pin** reamers have 1/4 inch taper per foot. They are used for reaming holes for standard taper pins, and are turned with a tap wrench. **Morse taper** reamers are tapered the entire length of the body and are available in roughing or finishing grades. **Burring** reamers (fig. 11) remove the burrs caused when pipe or tubing has been cut with a cutter.

Using Hand Reamers. Hand reamers are tapered a short distance on the end to allow the reamer to start in the hole. The tapered end is placed in the hole while the square part of the shank is gripped with a wrench and the reamer aligned by sight. After turning the reamer slightly to engage the hole, it is again squared by sight or by means of a square.

Grasp the wrench lightly in the center with the left hand to prevent the reamer from becoming misaligned while turning the wrench handle a few revolutions with the other hand. Again, check the alignment of the reamers, and repeat the above process with slight pressure from the left hand, forcing the tool into the hole as it turns.

Once it has been started straight, the reamer follows the hole with no further checking. Never turn the reamer counter-clockwise. To back it up causes small metal chips to catch under the cutting edges and dull the tool.

Exert slight pressure on the reamer until it is all the way through the hole. Then remove it by pulling gently on the

wrench while still turning the handle in a clockwise direction.

Reamer Care. When reaming steel, use a good grade of cutting oil. Cast iron is generally reamed dry, although many workers use a small amount of kerosene or turpentine if the cast iron is extremely hard. Do not use any kind of lubricant on soft cast iron.

When a hand reamer "chatters," it generally indicates that the reamer has not been correctly ground for the particular metal being reamed. Reamers should be selected according to the material to be reamed, as the grinding for the various metals is different. When a reamer begins to chatter, stop immediately and get another reamer. The pin or bolt must fit the hole. Taper-pin reamers are made with a reverse spiral, which prevents chatter, does not jam, and does not feed too fast. Reamers of this type often make smoother holes with less work on your part.

Exercise

1. What is the purpose of a tap?
2. What three taps come in a set?
3. What type of tap is used for blind holes?
4. Name the two types of tap wrenches.
5. How may tap breakage be reduced during tapping?
6. Why should a tap be backed off when tapping steel?
7. What device is used to remove a broken tap?
8. Which style of die is most commonly used?
9. What does the letter L stamped on a die or tap indicate?
10. What is the purpose of a ring, or guide, on a die?
11. What is the first step to take when threading?
12. What is the primary difference between pipe dies and other dies?
13. What does the pipe tap do?
14. What do reamers do?
15. Name the two types of flutes on reamers.
16. What machines are used with chucking reamers?
17. What generally causes a hand reamer to chatter?

D-1

Portable Electric Drills

Objectives: After completing this assignment, you will be able to—

1. discuss types of portable electric drills;
2. describe the uses of portable electric drills; and
3. discuss the rules for maintaining a safe and useful drill.

The portable electric drill (fig. 1) is used often by most millwrights. It may be used for drilling, sanding, polishing, grinding, and many other operations. It does these jobs with power, speed, economy, and convenience.

Types of Drills

Most workers use two basic types of drills, the small, all-around 3/8-inch drill and the larger 1/2-inch drill. These drills get their names from the dimension of the largest drill shaft that can be inserted in the chuck.

To reduce maintenance and to provide uninterrupted service, the quality electric drill uses two types of antifriction bearings. Precision ball bearings are used at the spindle to absorb radial and end thrust. For high-load capacity at the motor, oilless bronze bearings are used.

The handle of the 3/8-inch drill is a pistol-grip type, while the greater torque of the 1/2-inch drill requires two-handed control. A spade handle is placed on the rear housing.

The three main types of chucks are the geared chuck, the hex key chuck, and the hand-tightening chuck (fig. 2). All of these, when used properly, perform safely and efficiently. Proper insertion and tightening of the bit or drill in the chuck is essential for safe, efficient operation, regardless of the type of chuck used.

The geared chuck requires the use of a special key to open and close each of the three jaws at the same time. The bit is released by loosening only one jaw with the key and turning the collar to free the others. A special hex key opens and closes the hex key chuck. Use the aligning marks stamped into both the chuck body and the key socket as guides. To close the chuck, line up the marks, insert the bit, tighten it by hand, and then tighten it more with one turn of the key to the left or right. To release the jaws, align the marks once more and loosen the sleeve by hand. The hand-tightening chuck is operated by holding one collar tightly while turning the other one to open or close.

Wire Brush and Grinding Wheel

The wire brush and grinding wheel are generally used with a bench holder attachment or drill stand. They are used to remove tarnish or rust, sharpen hand tools, and remove peeling paint. When using the wire brush, hold the work firmly, keeping it on the bottom half of the brush. After prolonged use, the wire strands wear in one direction and become dull. When this happens, turn the brush around on the spindle, and it will again cut quickly. To sharpen brushes, place a grinding wheel against the tips of the strands while the wheel is revolving.

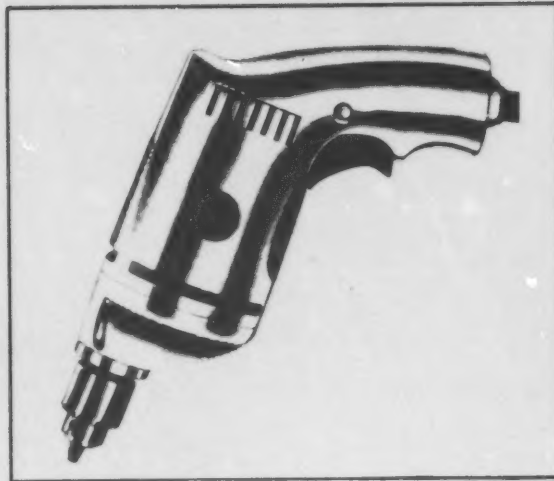


Fig. 1. Portable electric drill

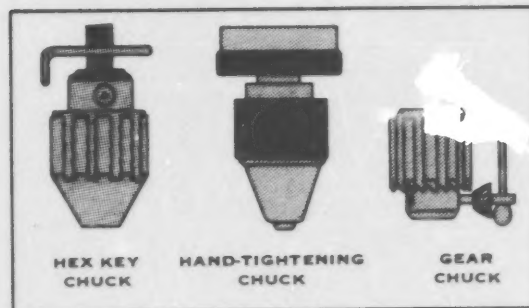


Fig. 2. Drill chucks

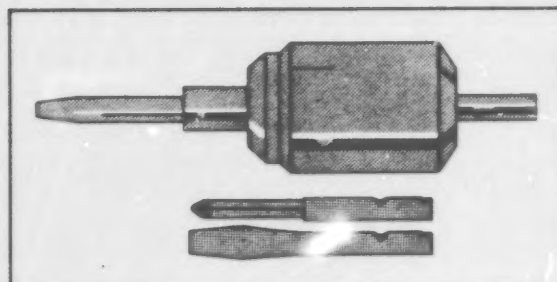


Fig. 3. Screwdriver attachments

Before mounting a grinding wheel, check it carefully for cracks. A cracked wheel can shatter during operation and cause serious injury. Do not remove the paper blotters on the wheel since they absorb pressure from the tightening nut and prevent the wheel from cracking. Light, steady pressure gives the best results. Bring the material into the wheel gradually to prevent gouging or slowing down the motor. Then move the material slowly back and forth across the face of the wheel to prevent overheating and uneven wear on the wheel. Wear goggles when using either the wire brush or grinding wheel.

Sanding attachments are available, but they are not used except for special jobs.

Screwdriver Attachments

Screwdriver attachments (fig. 3) are sometimes used to eliminate the slow task of driving screws by hand. These attachments are either the **friction** type or the **impact** type. The friction type is recommended for light finish work. Speed reducers and reversible screwdriver attachments enable a 3/8-inch drill to drive cutting tools with large diameters as well as heavy-duty screwdriver bits.

Using the Drill

Although many people own or have used electric drills, not everyone uses them properly. Before drilling, select the proper drill or bit for the particular job to be done. If the drill bit is dull or warped, do not use it. It will make a hole larger than you want. Use a prick punch or awl to start the hole in order to center the drill bit. Otherwise, the drill bit will not center properly or will move away from the proper location. This leaves undesirable marks on the surface of the wood or metal.

Tighten the bit securely into the chuck of the drill. Hold the drill in a stationary position so that it cannot be moved during the drilling operation. See that the drill is fastened to a properly grounded outlet. If possible, place scrap material behind the hole to be drilled. Turn on the switch for a few seconds to see if the bit is running true. Place the point of the drill bit into the punched hole, hold the drill firmly and at a 90° angle to the work, and apply even

pressure. Do not force this feed pressure. After drilling, unplug the drill and remove the drill bit from the drill.

Always keep in mind that this drill is **electric** and that precautions generally associated with electricity must be taken. Never use a damp drill or stand in water while using a drill. Never leave the drill plugged in when not in use. See that it is unplugged while making any adjustments.

When drilling, do not place your hand or fingers under or behind the stock being drilled. Do not remove the bit from the drill while it is hot unless you are wearing gloves or the drill bit can slip out without being touched.

Maintenance

A good electric drill is a precision tool and should be handled accordingly. After using the drill, blow all shavings and dust from the tool, and wipe off any oil or grease that has collected on it. Store the drill in a dry, safe place where it will not fall or have heavy objects thrown against it. Wrap the cord around it, or place it out of the way. Check the cord regularly for cuts, cracks, or kinks. Check the manufacturer's instructions for the particular drill before lubricating it.

Exercise

1. What sizes of portable electric drills do most workers use?
2. Name the two types of antifriction bearings used in portable drills.
3. Why does the 1/2-inch drill usually require two-handed control?
4. Name the three types of drill chucks.
5. What should you use with a portable drill when using a wire brush or grinding wheel?
6. Why should you not use a dull or warped drill bit?
7. What tool should be used to start a hole or center the drill bit?
8. What should you remember about drill feed pressure?
9. What safety device should you wear while grinding with a drill?
10. Why should paper blotters be left on grinding wheels?
11. What type of screwdriver attachment is recommended for light finish work?
12. What four steps should you follow after you have finished using a drill?

D-2

Portable Electric Circular Saws

Objectives: After completing this assignment, you will be able to—

1. describe sizes and features of portable circular saws;
 2. discuss the types of circular saw blades; and
 3. give maintenance procedures to take to protect circular saws.
-

Sizes and Features

The portable electric circular saw (fig. 1) is versatile, economical, and accurate. The sizes and prices of these circular saws vary considerably. Probably no one size can be considered ideal for all users. The size of the saw is rated according to the maximum blade size it will accept. On this basis, a saw with a 4 1/4-inch blade is rated small. An 8 1/4-inch blade is considered large. The most popular saws used in industry are usually the 7 1/4-inch and 8 1/4-inch sizes. This is because they can make deep or heavy cuts.

The two basic gear types are the worm drive and the helical gear saw. The worm drive is able to withstand sustained cutting longer, but the helical gear saw is much smoother to operate.

Two of the most important features of the portable electric saw are the bevel and depth adjustments. These are usually levers or knobs designed for positive locking and easy release when either depth or bevel is altered. Depth adjustments on the 6 1/4-inch saw run from a minimum of about 1/16 inch to a maximum of about 2 3/16 inches. They run from 1/16 inch to 2 7/8 inches on the 8 1/4 inch saw. Bevel adjustments are calibrated on the saws from 0° to 45°.

A telescoping safety guard shields the lower part of the blade, reducing the

number of exposed sawteeth. The guard also has a retractable handle for extra safety in making pocket cuts.

Portable electric saws usually have a clutch arrangement that consists of three parts: (1) the saw stud that secures the blade to the saw, (2) an outer washer keyed to the drive shaft of the saw, and (3) an inner washer keyed to the blade itself. The outer washer transmits the drive. The inner washer becomes the slipping clutch element. When the saw binds in a cut, the inner washer slips with the blade. The drive spins freely, protecting the motor, gears, and bearings from undue impact.

Circular Saw Blades

You should keep several saw blades on hand at all times. If the saw blade becomes dull and another blade is not available, you must either stop and sharpen it or wait to have it sharpened. Either way, work is interrupted. You also need different types of blades for different materials or different cuts.

A **crosscut** saw blade (fig. 2) is used for cutting wood across the grain. The teeth of this blade resemble knife points. They are useful in cutting across the fibers of the wood. The **ripsaw** blade (fig. 3) resembles a group of chisel points placed together. It is used for ripping or cutting parallel with the fibers of the wood.



Fig. 1. Portable electric circular saw

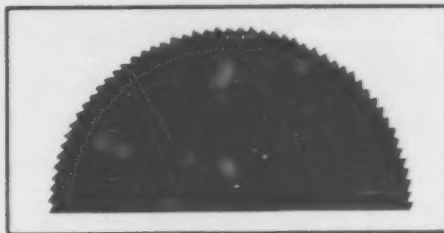


Fig. 2. Crosscut saw blade

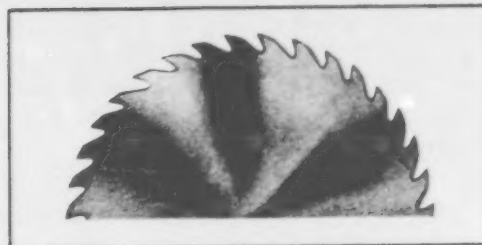


Fig. 3. Ripsaw blade



Fig. 4. Combination saw blade

The **combination** saw blade (fig. 4) has both crosscut and rip saw teeth and can be used for both crosscutting and ripping. This blade has four cutting teeth and one raker tooth in each group. The raker tooth removes saw chips. The gullets (openings between the teeth) are larger and deeper than those of the other two blades. Because it combines both blades, the combination blade must be fed into the material at a slower rate.

Another blade that can be used for crosscutting, ripping, and angle cutting is the hollow-ground combination saw blade. The blade is thicker at the cutting edge than at the body. It makes a very smooth cut. Other saw blades are the carbide-tipped blade, the plywood blade, and the miter blade. The carbide saw blade is popular because it dulls slowly and makes a very smooth cut. It is also quite expensive.

Using the Portable Circular Saw

Crosscutting. When crosscutting, adjust the depth of the saw cut so that only about 3/8 inch of the saw blade protrudes through the material. Remove the ripping guide or place it out of the way of the saw cut. Make sure that all nuts and thumbscrews are tight before you turn on the saw. Be sure the saw is clear of any material before turning it on. Hold the material so that it will not slip. With one hand on the material, guide the saw along the mark with the other hand. Use the crosscut guide on the saw. Feed the saw into the wood, but do not move it at a pushing speed that might slow the saw down or cause it to stall. Wear goggles to protect your eyes from flying dust and chips. After the saw is completely through the material, release the trigger that keeps the saw engaged.

Ripping. When ripping, use the same precautions as for crosscutting. Position the ripping guide on the outside edge of the material to be ripped. The body of the saw must always be rested on the material to be used, with the scrap material outside the blade. Adjust the guide so that the saw cuts to the proper width. If you will be edging later, allow for jointer removal. Tighten the ripping guide into place, and check the other adjustments for tightness. Push the saw forward while the ripping guide slides along the edge of the board.

Sometimes you will need to cut material that has already been fastened to a structure. In this situation, always be securely balanced. If the saw binds or twists, and you are not balanced, you could be thrown off balance.

Angle Cutting. For angle cutting, loosen the thumbscrew for the angle adjustment, then turn the saw to the required angle. The angles are marked on an angle scale. Adjust the saw to the correct depth. Check the angle by cutting a piece of waste material and comparing it with a sliding T bevel or protractor. Move the saw slowly, as the saw is more likely to bind when angle cuts are being made.

Care and Maintenance

Like other portable tools, the portable electric circular saw should always be stored in a clean, dry place. Do not leave it where it may fall or where heavy objects may be thrown against it. Lubricate it periodically, especially when it has been used for long periods of time or for heavy work. Check the cord for cracks or cuts. See that all adjustments are tight.

The saw blades should be kept hanging on a wall or between pieces of cardboard. Some millwrights place waxed paper next to the blades while they are in storage. A thin layer of oil or wax on the blades keeps them free of rust. Keep blades sharp and set at all times. Remember that you can be cut very quickly, whether the saw is moving or at rest. Always know where the cutting edges or teeth are when you are sawing.

Exercise

1. What sizes of portable circular saws are the most popular in industry?
2. What two basic types of gears are found in portable circular saws?
3. What is the purpose of a telescoping safety guard on a portable circular saw?
4. Name four saw blades commonly used on the portable circular saw.
5. How much should the saw blade protrude through the material while sawing?
6. What accessory should be used when ripping with a portable circular saw?
7. What is more likely to happen when angle cuts are made?

8. What part of the clutch arrangement transmits the drive?
9. What is protected by having a clutch arrangement?

10. How should you protect the saw blade from rust?
11. How should you check an angle before making angle cuts?

E-1

Bolts, Nuts, and Washers

Objectives: After completing this assignment, you will be able to—

1. describe types of bolts and their manufacturing standards;
2. discuss the various types of nuts; and
3. describe types of lock nuts and washers.

Bolts

Millwrights fasten parts or assemblies together, as well as disassemble them. These units may be large equipment or platforms and bases for the equipment. Bolts are often used during this process, as they are strong, yet can be unfastened easily.

A bolt is a threaded rod that is used with a nut to fasten the parts together. The head and nut of a bolt are generally square or hexagonal in shape and are tightened by means of a wrench. The size of a bolt is usually given in a fractional inch, such as 1/2 inch, 5/16 inch, etc. Some bolts are also available in metric sizes.

Certain standards apply to the manufacture of all bolts in the United States. This is usually called the American Standard, although some workers may still refer to it as the National Standard. The threads per inch by the American Standard are shown in table 1. Such a table is useful for finding the proper bolt for a certain tapped hole, for replacing a nut on a bolt, or for drilling and tapping a hole for a bolt. Notice in table 1 that the thread form is divided into two principal series, coarse and fine. This has to do with how many threads are in 1 inch on bolts of the same diameter. A bolt with a hexagon head, 1/4 inch in diameter and 2 1/2 inches in length, may have National Standard threads of either the coarse series (NC) or the fine series (NF). If

you are ordering one of each of these bolts, they would appear in a catalog as:

1/4-20X2 1/2 (NC)Hex Head Bolt

1/4-28X2 1/2 (NF)Hex Head Bolt

The numbers 20 and 28 refer to the number of threads per inch for each thread series.

The dimensions of a bolt are found by using its diameter (D) as the unit of measurement (fig. 1). The diameter of a bolt is the diameter of the body. The length is measured from the underside of the head to the end. The head size of a bolt (W) is the wrench size. It is the distance between any two opposite faces, or flat sides, of the head.

When bolts are referred to in orders, parts lists, or correspondence, a standard manner of designating information is used. The data is given in this order: (1) diameter, (2) length, (3) type of thread, (4) finish, (5) type of head, and (6) name. This information is usually abbreviated as follows:

1/2 X 2 1/4" - 20NF - 2 Fin. - Hex Machine Bolt

The most common types of bolts for general industrial purposes are machine bolts, stove bolts, carriage bolts, stud bolts (or studs), and hanger bolts. These are shown in figure 2. Most of these bolts are used by the millwright at various times.

There are also certain strength requirements for bolts that are used to fasten parts together or to anchor equipment to bases. The Society of Automotive Engineers (SAE)

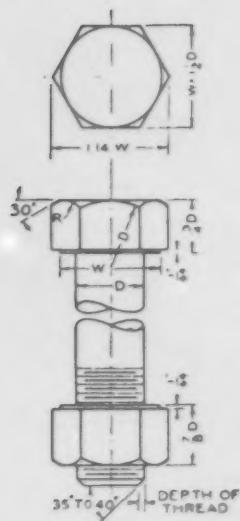


Fig. 1. Bolt dimensions

Table 1
AMERICAN (NATIONAL) STANDARD THREADS

Nominal Size	Major Diameter (Inches)	Coarse Thread Series			Fine Thread Series		
		Threads per Inch	Tap-Drill Size	Tap-Drill Diameter	Threads per Inch	Tap-Drill Size	Tap-Drill Diameter
0	0.0600				80	$\frac{3}{64}$	.0469
1	.0730	64	53	.0595	72	53	.0595
2	.0860	56	50	.0700	64	50	.0700
3	.0990	48	47	.0785	56	45	.0820
4	.1120	40	43	.0890	48	42	.0935
5	.1250	40	38	.1015	44	37	.1040
6	.1380	32	36	.1065	40	33	.1130
8	.1640	32	29	.1360	36	29	.1360
10	.1900	24	25	.1495	32	21	.1590
12	.2160	24	16	.1770	28	14	.1820
$\frac{1}{4}$	.2500	20	7	.2010	28	3	.2130
$\frac{5}{16}$	.3125	18	F	.2570	24	I	.2720
$\frac{3}{8}$	.3750	16	$\frac{5}{16}$	.3125	24	Q	.3320
$\frac{7}{16}$	.4375	14	U	.3680	20	$\frac{25}{64}$	.3906
$\frac{1}{2}$	.5000	13	$\frac{27}{64}$	.4219	20	$\frac{29}{64}$	.4531
$\frac{9}{16}$	.5625	12	$\frac{31}{64}$	.4844	18	$\frac{33}{64}$	.5156
$\frac{5}{8}$	.6250	11	$\frac{17}{32}$	.5312	18	$\frac{37}{64}$	.5781
$\frac{3}{4}$	.7500	10	$\frac{21}{32}$	.6562	16	$\frac{11}{16}$	.6875
$\frac{7}{8}$	.8750	9	$\frac{49}{64}$	.7656	14	$\frac{13}{16}$	.8125
1	1.0000	8	$\frac{7}{8}$	.8750	14	$\frac{15}{16}$	.9375
$1\frac{1}{8}$	1.1250	7	$\frac{63}{64}$	.9844	12	$\frac{13}{64}$	1.0469
$1\frac{1}{4}$	1.2500	7	$1\frac{1}{64}$	1.1094	12	$1\frac{11}{64}$	1.1719
$1\frac{1}{2}$	1.5000	6	$1\frac{11}{32}$	1.3437	12	$1\frac{27}{64}$	1.4219
$1\frac{3}{4}$	1.7500	5	$1\frac{9}{16}$	1.5625	12	$1\frac{49}{64}$	1.6718
2	2.0000	$4\frac{1}{2}$	$1\frac{25}{32}$	1.7812	12	$1\frac{59}{64}$	1.9218
$2\frac{1}{4}$	2.2500	$4\frac{1}{2}$	$2\frac{1}{32}$	2.0312	12	$2\frac{11}{64}$	2.1718
$2\frac{1}{2}$	2.5000	4	$2\frac{1}{4}$	2.2500	12	$2\frac{27}{64}$	2.4218
$2\frac{3}{4}$	2.7500	4	$2\frac{1}{2}$	2.5000	12	$2\frac{49}{64}$	2.6718
3	3.0000	4	$2\frac{3}{4}$	2.7500	10	$2\frac{29}{32}$	2.9062

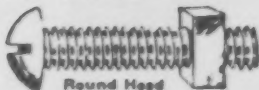
NOTE: Tap-drill sizes given allow for a thread having approximately 75 percent of the full depth and are for Class 2 fit.



Machine Bolt



Flat Head

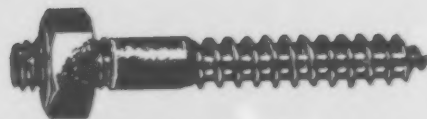


Round Head

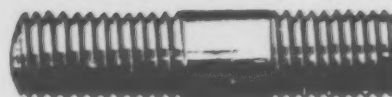
Stove Bolts



Carriage Bolt



Hanger Bolt

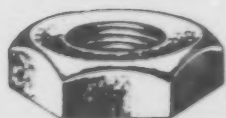


Nut End

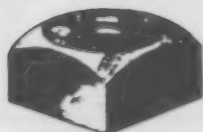
Tap End

Steel Stud

Fig. 2. Common bolts



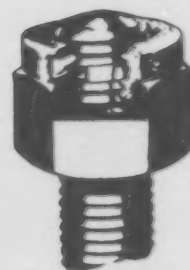
Hexagon Jam Nut



Square



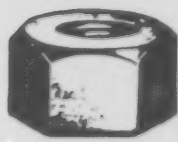
Cap Nut



Self-Locking Nut



Wing



Hexagon



Slotted



Castellated Nuts

Fig. 3. Common nuts

has established grades such as Grade 2, Grade 3, Grade 5, etc. The American Society for Testing and Materials (ASTM) also has designations such as A-307, A-409, A-325, etc. You should have a list of these grades and designations so you will know which bolts should be used on specific jobs.

It would not be cost efficient to use a Grade 8 bolt to fasten two piece of mild steel together, because the extra strength of this bolt is not necessary. It would also be unsafe to depend on an A-307 bolt for a structural connection, as it could easily shear under the stresses that take place.

Nuts

Nuts are of the same size, thread form, and pitch as the bolts they fit. The standard hexagon nut is also the same diameter as the bolt head, but somewhat thicker. The thread of a nut is internal (female), and the same thread standards just discussed apply to nuts. Usually the sharp corners on square and hexagon nuts are chamfered to prevent injury to the hand.

Nuts are designed in several types to suit different needs (fig. 3). The most common types are square, hexagon, slotted hexagon, castle (or castellated), cap (or standard), light (or half nut), and jam (or lock). The jam nut is the thinnest and is used with another nut, usually a light or half nut, to lock it on the bolt.

Small thin nuts are sometimes incorrectly called "taps" in certain parts of the country. A tap is a fluted, threaded tool for cutting inside threads.

Lock Nuts and Washers

Practically all nuts should be used with a washer of some type. However, some nuts have special safety devices that make this unnecessary. The slotted and castellated nuts (fig. 3) are used with cotter pins or safety wire to prevent them from loosening on the bolt. A few types of lock nuts, originally designed for the aircraft industry but now used in sheet-metal assemblies, are shown in figure 4.

Spring steel nuts, such as those shown in figure 4 (A, B, and C), are a popular class of nuts since they can be installed very quickly and combine the functions of nuts and lock washers. The speed nut (fig. 4A)

has two forked prongs that engage the thread of the bolt and that are sprung inward to engage the bolt tightly when the nut is tightened. These nuts have many uses where little strain is encountered. They are made in angle brackets (fig. 4B), as well as in long metal strips with several "nuts" stamped at desired intervals.

Another type of spring steel fastener is the "Stalock" fastener (fig. 4C), which grips the thread almost one complete round. This nut may be reused, whereas many other types are sprung with the first use.

A completely different type of lock nut is shown in figure 4 (D and E). It has two threaded portions through which the screw turns. Each is slightly out of "pitch" with the other, causing a compressive action as the nut is tightened.

Lock washers are of several types. The most common is the split ring type shown in figure 4. Other types have come from the aircraft industry, which required lightweight washers with great holding power and the ability to withstand severe vibration. These are put into a general class known as "shakeproof" washers and come in two main styles. They have twisted, tapered teeth that engage both the nut and the work so as to make loosening unlikely. Those with inside teeth are for use with fillister head screws. Those with outside teeth are for use with hexagon and square nuts and screw-heads.

Exercise

1. Define a bolt.
2. How is an American (National) Standard table for bolts useful when working with various assemblies?
3. Name the two principal series of a bolt thread form.
4. What does the number 20 refer to in a catalog listing such as "1/4-20 X 2 1/2 (NC) Hex Head Bolt"?
5. Where is the length of the bolt measured from?
6. Why are the corners on square or hexagon nuts usually chamfered?
7. Which nuts are used with cotter pins or safety wire?
8. Which nut may be reused several times?
9. What is the most common type of lock washer?

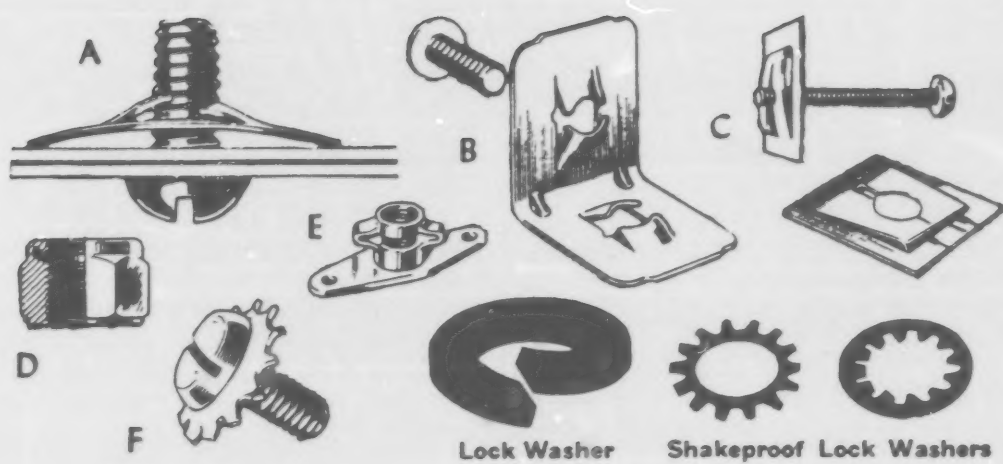


Fig. 4. Lock nuts and washers

E-2

Screws, Nails, and Rivets

Objectives: After completing this assignment, you will be able to—

1. describe the types and uses of various screws;
 2. discuss types of nails used by a millwright; and
 3. give the types and uses of rivets.
-

Screws

Although a few types of screws are designed to be tightened with a wrench, most of them have slots or sockets for engaging the blade or bit of a screwdriver or a specially designed wrench. Types of screwheads are shown in figure 1. The most common screwheads and the driving devices used most often with them are described below.

1. Slotted-head screws are intended for use with the conventional type of screwdriver.
2. Hexagon socket heads (or allen heads) are used with the L-shaped, hexagonal allen wrench or key.
3. Phillips-head screws have a cross-shaped recess and are used with a Phillips screwdriver. Their main advantages are ease of starting, attractive appearance, and the fact that the screwdriver cannot slip out of the screwhead while it is turning.
4. Reed and prince heads (crossheads) are somewhat similar to the Phillips head and are used with a specially formed screwdriver bit.
5. Spline socket heads (fluted heads) require a special splined wrench that permits a maximum amount of force to be applied without splitting or straining the screwhead.

6. Clutch heads are used with a special screwdriver bit designed to permit considerable turning force.

As a millwright, you should always have the correct type and size of driver for the screws you will be using.

The largest screw for fastening two pieces of metal together is the **cap screw** (fig. 2). It passes through a clearance hole in one piece and fastens it by screwing into a tapped hole in the second piece. Cap screws are available with threads of either the National Coarse or National Fine series.

The heads of cap screws are of five general types: hexagon, flat, button, fillister, and socket (or recessed). The hexagon head is the most common type used in sheet-metal assemblies.

Self-tapping screws, also called **Parker screws** and **sheet-metal screws**, resemble ordinary wood screws, except they are shorter and have threads the entire length of the screw. They are used primarily to fasten thin metal parts and sheet metal together, but they are also used with plastics. The screws are of very hard metal, and the threads "form" rather than "tap" threads in the metal into which they are screwed. One type, however, actually taps threads into a drilled hole. It resembles a machine screw with slits along the end, which gives cutting edges at each thread



Fig. 1. Types of recessed heads



Fig. 2. Cap screws

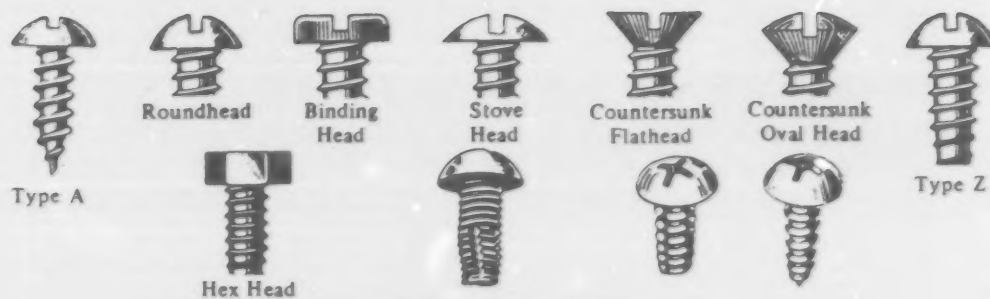


Fig. 3. Self-tapping screws

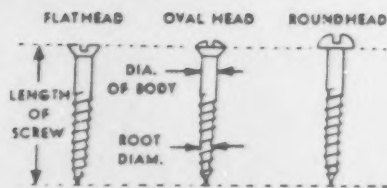


Fig. 4. Measuring wood screws

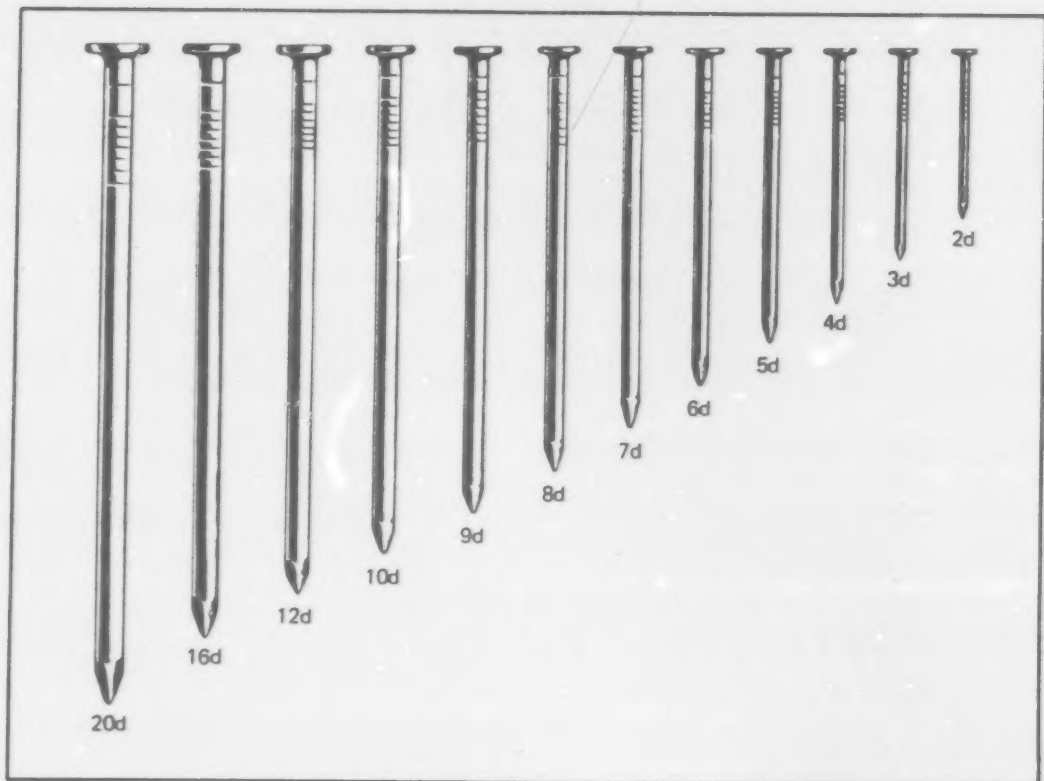


Fig. 5. Common wire nails

that tap the threads as the screw is tightened.

Parker self-tapping screws are made in two types, A and Z, and have six different types of heads (fig. 3) in addition to the slotted or Phillips recessed head.

Drive screws are a combination of screw and nail. They are used chiefly to fasten sheet metal, plastics, leather, and paper to wood by driving them most of the way in, then tightening with a turn or two of the screwdriver. One type of drive screw, designed for metal work, is made of hardened steel and is used to fasten thin metal parts to brass, aluminum, and iron castings. The screw is driven all the way in with a hammer after it has been started in a hole drilled to the proper size to receive it.

Wood screws pass through a clearance hole in one piece of material and fasten it by screwing into the second piece. The heads of wood screws are of three standard types—flat, oval, and round. They are available in both the slotted and Phillips heads. The method of measuring length is shown in figure 4. The diameters of wood screws are given in gauge sizes from No. 0 to No. 20. The larger the number, the larger the diameter.

The common finishes or materials from which wood screws are manufactured are steel (bright), brass, copper, cadmium- and zinc-plated, galvanized, parkerized, and blued. When ordering wood screws, the data should be given in this order: (1) length, (2) gauge, (3) head, and (4) finish. For instance, a screw that is 10 gauge, 1 1/4 inches long, with an oval head and cadmium plating, would be shown as:

1 1/4" - No. 10 - O.H. Cad. Plated

Nails

Most modern nails are made from steel wire, but they are available in various other metals. When the nail separates the wood fibers, they try to return to their original position, trapping the nail inside. This gives the nail what is known as "holding power." The millwright normally uses five types of nails. They are common wire nails, box nails, finishing nails, casing nails, and staging (duplex head) nails.

Common Wire Nails. Common wire nails are shown in figure 5. These nails are

available in sizes 2d (domestic) to 60d. Sizes larger than 20d, called spikes, are normally used in very heavy construction, such as machinery platforms. The 16d or 20d nails are used mainly in building up corner posts, girders, and plates. They are also used for fastening rafters, braces, and studs in place. These nails are 3 1/2 and 4 inches long (table 1).

The 8d nail is widely used in fastening wall sheathing and subflooring to framework. This nail is 2 1/2 inches long and about 1/8 inch in diameter. It is made from No. 10 1/4 wire.

Common wire nails are available in various heads and points. The diamond point and simple round head are most popular. The 8d and larger common wire nails are usually found with a countersunk head. This helps you to drive the head flush with the wood.

Box Nails. Box nails (fig. 6) are similar to common nails. But they have a smaller diameter and thinner heads. They are used for applications such as fastening the sub-floor to floor joists or where a great amount of strength is not required.

Finishing Nails. Finishing nails (fig. 7) are used for interior and exterior finishing work. These nails are smaller in diameter and length. They have a small head that is usually set below the surface of the wood. This leaves a small hole or indentation that is filled with putty or filler.

Casing Nails. Casing nails (fig. 8) are similar to finishing nails except that the diameters of both the head and the body are slightly larger. These nails are used for fastening both interior and exterior trim. After they have been nailed flush with the wood, they are pushed below the surface of the wood with a hammer and nail set. The hole is filled and sanded flush with the wood. The most common sizes used are the 8d and the 10d.

Staging (Duplex Head) Nails. Staging nails (fig. 9) are used chiefly for temporary construction work. Each one looks as though it has two heads. They are constructed much like the common nail in size and strength. If temporary bracing is needed, the nail is driven until the lower head has locked against the wood. The nail provides maximum strength, but the outer head still projects, making removal easier.

TABLE 1
Nail Sizes

Common Wire Nails							
Size	Length (in.)	Gauge	Approx. no. / lb.	Size	Length (in.)	Gauge	Approx. no. / lb.
2d	1	15	876	10d	3	9	69
3d	1¼	14	568	12d	3¼	9	63
4d	1½	12½	316	16d	3½	8	49
5d	1¾	12½	271	20d	4	6	31
6d	2	11½	181	30d	4½	5	24
7d	2¼	11½	161	40d	5	4	18
8d	2½	10¾	106	50d	5½	3	14
9d	2¾	10¾	96	60d	6	2	11

Finishing Nails				Casing Nails			
Size	Length (in.)	Gauge	Approx. no. / lb.	Size	Length (in.)	Gauge	Approx. no. / lb.
2d	1	16½	1,351	2d	1	15½	1,010
3d	1¼	15½	807	3d	1¼	14½	635
4d	1½	15	584	4d	1½	14	473
5d	1¾	15	500	5d	1¾	14	406
6d	2	13	309	6d	2	12½	236
7d	2¼	13	238	7d	2¼	12½	210
8d	2½	12½	189	8d	2½	11½	145
9d	2¾	12½	172	9d	2¾	11½	132
10d	3	11½	121	10d	3	10½	94
12d	3¼	11½	113	12d	3¼	10½	87
16d	3½	11	90	16d	3½	10	71
20d	4	10	62	20d	4	9	52
				30d	4½	9	46

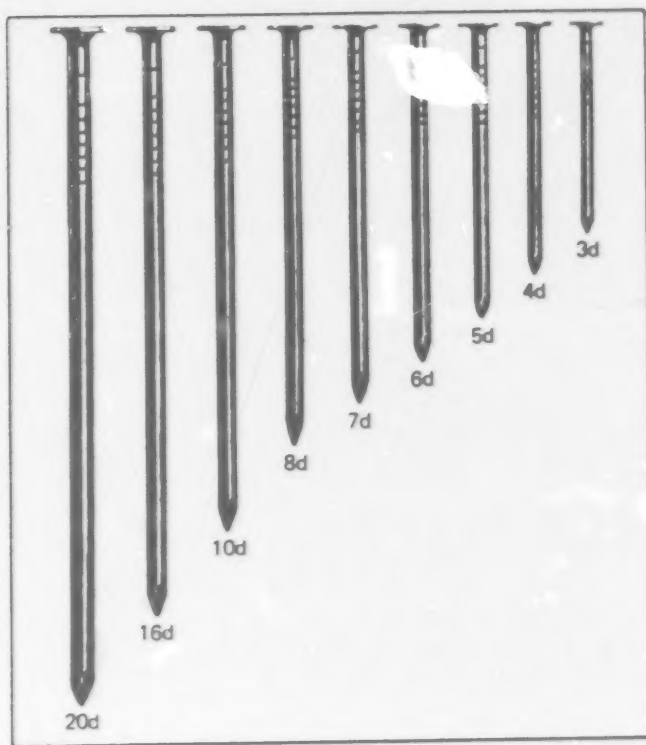


Fig. 6. Box nails

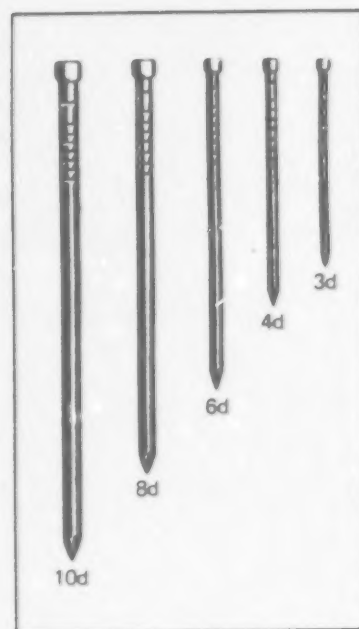


Fig. 7. Finishing nails

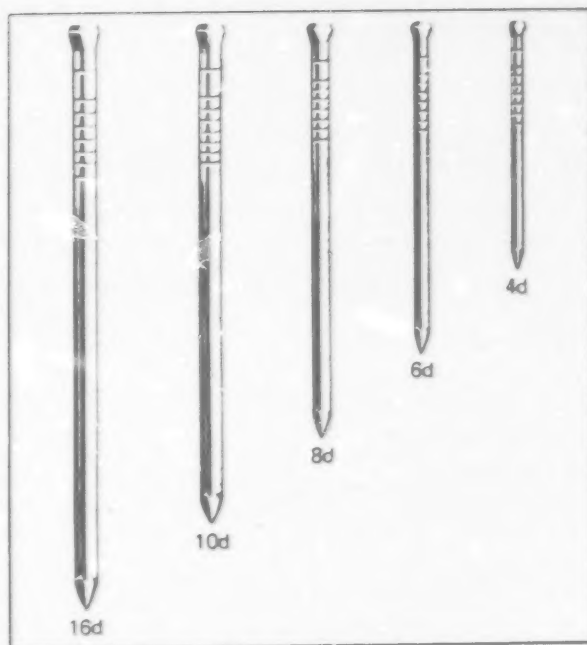


Fig. 8. Casing nails

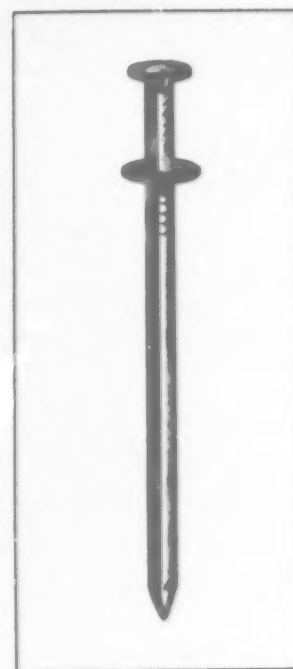


Fig. 9. Staging (duplex head) nail

Rivets

Rivets are used to fasten together two pieces of metal that are not likely to be disassembled later. Riveting is the "upsetting" of the end of the rivet shank, which has been passed through punched or drilled holes in the metal pieces. "Upsetting" is the forming of a second head by shaping the end of the rivet while the head is held firmly in place (bucked) with a bucking bar or dolly that is usually held by another person. The ends of the rivets are "upset" by hammering or peening with a rivet set and hammer or with pneumatic hammers called rivet guns.

The most common types of rivet heads are shown in figure 10. **Countersunk rivets** are used where streamlining is necessary to prevent drag due to air or water flow and for appearance. **Brazier-head rivets** are used where countersinking is not practical and where drag must be kept as low as possible by making the rivet heads thin. **Roundhead rivets** are used where maximum strength is important and other features are not necessary. **Flathead rivets** are used for general purposes where both strength and compactness are important. **Tinner's rivets** are of this type. They are made of soft steel that is usually coated with tin to prevent rusting.

Rivets are gauged by weight per 1,000, starting with 10 ounces (1,000 rivets of this size weigh 10 ounces). The most commonly

used rivets are gauged 2, 2 1/2, and 3 pounds. A 2-pound rivet will fit in a 5/32-inch hole.

One problem in using ordinary rivets is that both sides of the work must be accessible for driving and bucking. For places where only one side of the work can be reached, several types of "blind" rivets can be used. Most have a metal screw or plug inside the hollow rivet that compresses and upsets the end when the screw or plug is withdrawn. One type of blind rivet uses a small explosive charge in the hollow end that explodes when heat is applied to the head. The impact upsets the end of the rivet, locking the sheets of metal together.

Exercise

1. What is the largest screw for fastening two pieces of metal together?
2. What are self-tapping (Parker) screws primarily used for?
3. How are drive screws driven in?
4. Name the three standard types of heads of wood screws.
5. How are nails sized?
6. How are the ends of rivets "upset"?
7. Describe tinner's rivets.
8. What type of rivet is used where only one side of the work can be reached?
9. How are rivets gauged?
10. What are nails larger than 20d called?

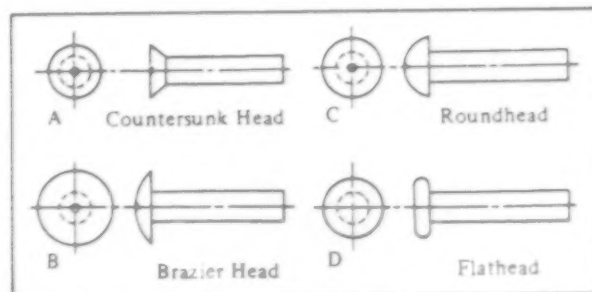


Fig. 10. Rivets

F-1

Gear Systems

Objectives: After completing this assignment, you will be able to—

1. name the types of gears and tell how they work;
2. discuss worms and worm wheels; and
3. discuss how gears are used to change direction and speed and to magnify force.

How Gears Work

As a millwright, there will be times when you will be involved in the installation or repair of gear systems. Many machines rely on gears for various types of operations. They have the advantage of giving a positive drive, whereas a belt drive may creep or slip.

An egg beater is a simple example of how gears work (fig. 1). Gears in this device can change the direction of motion, increase or decrease the speed, and magnify or reduce the force. By looking at figure 1, you can see how directional changes are made through the use of gears. The crank handle is turned in the direction indicated by the arrow. This is a clockwise direction, if you view it from the right. The 32 teeth on the larger vertical wheel (A) mesh with the 8 teeth on the right-hand horizontal wheel (B), which rotates as shown by the arrow. The small wheel (B) turns in a clockwise direction and meshes with the teeth of wheel C. This causes wheel C to revolve in the opposite direction. The rotation of the crank handle has been transmitted by gears to the beater blades and causes them to rotate.

The gears also change the speed of motion. As mentioned before, there are 32 teeth on gear A and 8 teeth on gear B. This means that one complete revolution of gear

A causes gear B to make four complete revolutions. Gears B and C have the same number of teeth, so one revolution of gear B causes gear C to revolve one complete turn. Therefore, the blades revolve four times as fast as the crank handle.

When using the egg beater, the magnitude of the force is changed. The force required to turn the handle is greater than the force that is applied by the blades. This results in a mechanical advantage of less than one, so the advantage of increased speed is at the expense of force.

Types of Gears

Spur Gears. When two shafts are not lying in the same straight line, but are parallel, motion can be transmitted from one to the other by means of spur gears (fig. 2). Spur gears are wheels with mating teeth cut in their edges. One gear can turn the other without slippage. When the mating teeth are cut so they are parallel to the axis of rotation, they are known as **straight spur gears**.

Sometimes two gears of different sizes are meshed together. The smaller of the two is usually called a **pinion**. The gears can be of different sizes, but the teeth must be the same size so they will mesh properly.

Another type of spur gear is the **helical spur gear**. This type has teeth that are cut

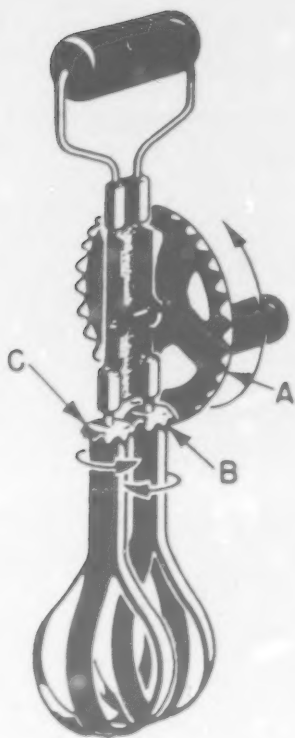


Fig. 1. A simple gear arrangement

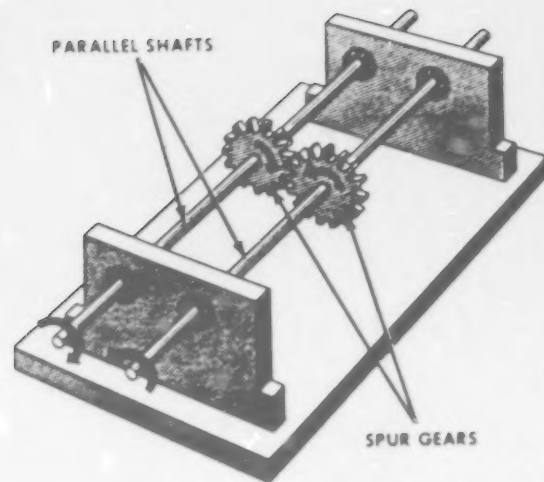


Fig. 2. Transmitting motion using spur gears

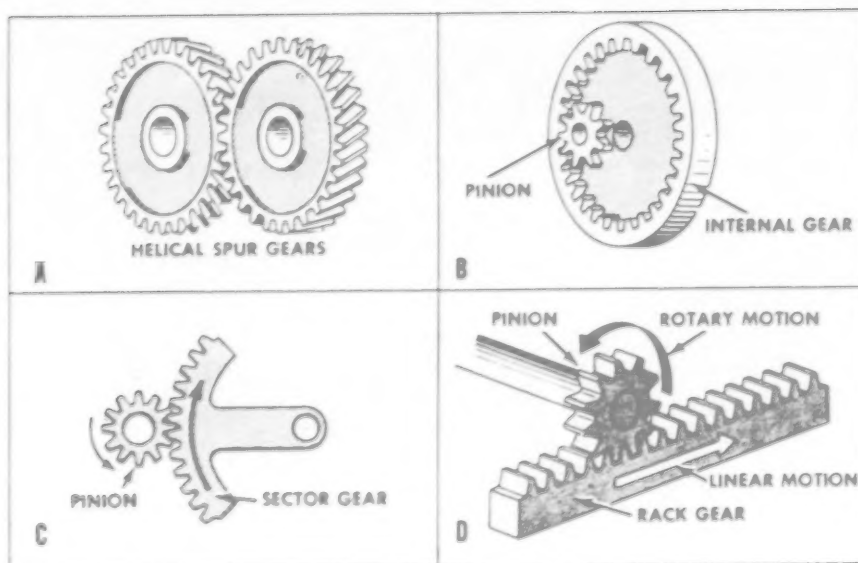


Fig. 3. Types of gears

slantwise across the edge of the gears. One end of the tooth lies ahead of the other; therefore, each tooth has a leading end and a trailing end. An example is shown in figure 3A. In the straight spur gears, the whole width of the teeth comes in contact at the same time. But helical (spiral) gears come in contact first at the leading ends, then move across the gear edges until the trailing ends are in contact. This type of meshing action keeps the gears in constant contact with one another with less lost motion and smoother action.

One disadvantage of the helical spur gear is that each gear may thrust or push axially on its shaft. This can be eliminated by placing a special thrust bearing at the end of the shaft to counteract this tendency. Thrust bearings are not necessary if **herringbone gears** (fig. 4) are used. The teeth on each half of a herringbone gear are cut in opposite directions, so each half of the gear develops a thrust to counterbalance the thrust of the other half. Herringbone gears are found on most heavy equipment.

The **internal gear** (fig. 3B) has teeth on the inside of a ring, which point inward toward the axis of rotation. This gear is always meshed with an external gear, or pinion, with the center offset from the center of the internal gear. Either the internal gear or the pinion gear can be the driver gear.

Sometimes only a portion of a gear is needed where the motion of the pinion is limited. In this case, the **sector gear** (fig. 3C) is used to save space and material. The **rack and pinion gears** shown in figure 3D are both classified as spur gears. The rack looks like a piece cut from a gear with a very large radius. This gear arrangement is used for changing rotary motion into linear motion.

Bevel Gears. Bevel gears are used when shafts are not parallel. They can be used to connect shafts lying at any angle because they can be beveled to match the angle. One type of bevel gear, the **miter gear** (fig. 5A), is used to connect shafts that are at 90° to each other. Each gear edge is beveled at a 45° angle. If gears are cut at angles other than 45° , they are called **plain bevel gears** (fig. 5B).

Spiral bevel gears (fig. 6) are a variation of bevel gears. They have the same

advantages as other spiral (helical) gears by having less lost motion and smoother, quieter operation.

Worms and Worm Wheels

Worms and worm wheel combinations are used often in various types of machinery. A single-thread worm is shown in figure 7A. When the worm has made one complete revolution, the worm wheel turns one tooth. This means that if a worm wheel has 15 teeth, the gear ratio is 15:1.

A double-thread worm is shown in figure 7B. When this type of worm makes one revolution, the worm wheel turns two teeth. The gear ratio for a worm wheel with 15 teeth is 15:2. There is also a triple-thread worm.

Since a worm gear is a combination of a screw and a spur gear, there are a number of mechanical advantages. Worm drives can be designed so that the worm is the driver and the spur cannot drive the worm. If this type of gear system is used on a hoist, you can raise or lower a load by pulling on a chain which turns the worm. If you release the chain, the load cannot drive the spur gear to let the load drop. It is called a nonreversing worm drive and provides safety to the operator.

Directional Changes with Gears

Some equipment or adjusting devices must be able to move in both forward and reverse directions. Figure 8 shows how gears are used to change the direction of motion. If you crank the handle A in a clockwise direction, the gear B directly above it rotates in a counterclockwise direction. This motion causes the two pinions C and D on the shaft to turn in the same direction as gear B against the teeth cut in the bottom of the device. The device is moved in the direction indicated by the arrow.

As you turn handle E in a clockwise direction, the gear F directly above it turns in the opposite direction. Since the two bevel gears G and H are fixed on the shaft with F, they also turn. These bevel gears, meshing with the horizontal bevel gears I and J, cause I and J to swing the front ends of the small telescope shown to the right.

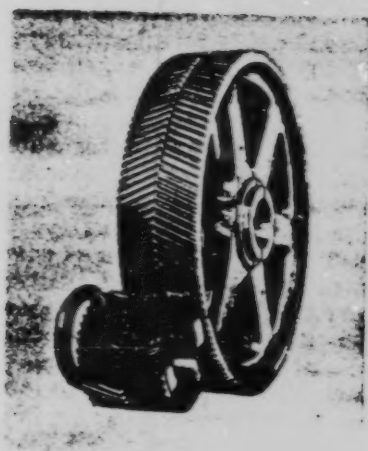
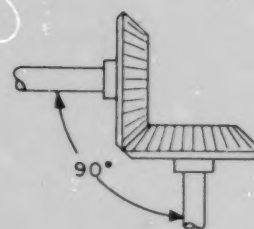
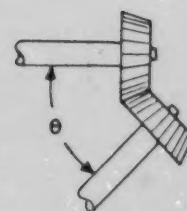


Fig. 4. Herringbone gears



A. MITER GEAR



B. BEVEL GEAR

Fig. 5. Bevel gears

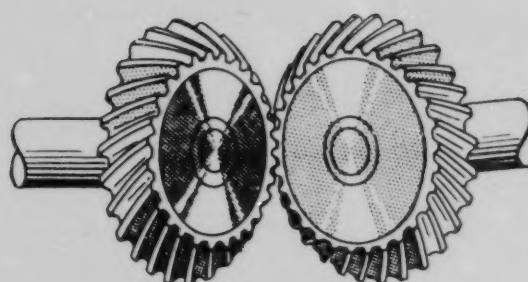


Fig. 6. Spiral bevel gears

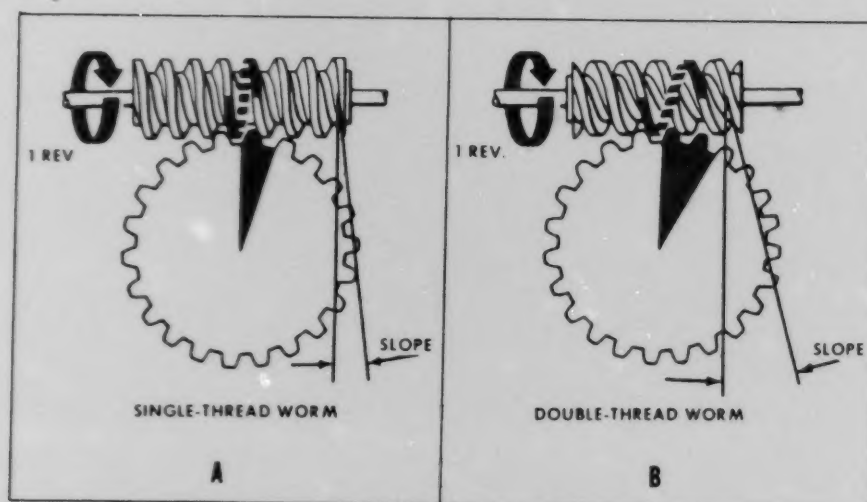


Fig. 7. Worm gears

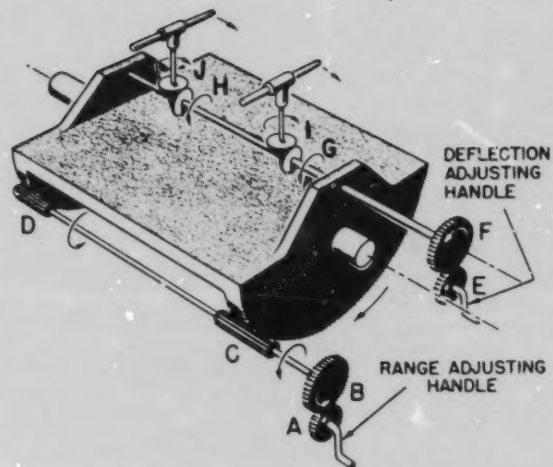


Fig. 8. Using gears to change direction of motion

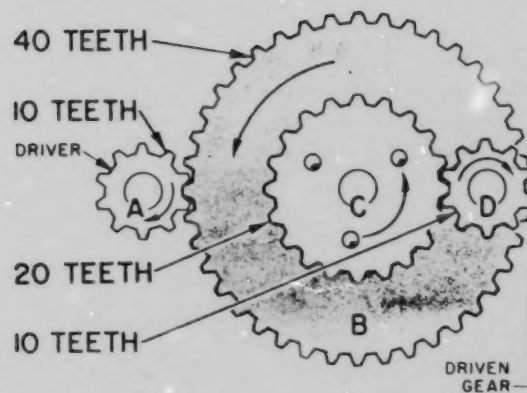


Fig. 9. Changing speeds with gears

Speed Changes with Gears

Although you will be working with much heavier equipment, a clock or watch is a good example of changing speeds by gears. The mainspring slowly unwinds and causes the hour hand to make one revolution in 12 hours. Through a series of gears, the minute hand makes one revolution each hour, while the second hand goes around once per minute.

Figure 9 shows how speed changes are made. Wheel A has 10 teeth, which mesh with the 40 teeth on wheel B. Wheel A will have to rotate four times to cause B to make one revolution. Wheel C is rigidly fixed on the same shaft with B, so C makes the same number of revolutions as B. Wheel C has 20 teeth and meshes with wheel D, which has only 10 teeth. This means wheel D turns twice as fast as wheel C.

If you turn wheel A at a speed of four revolutions per second, wheel B will be rotated at one revolution per second. Wheel C also moves at one revolution per second, which causes wheel D to turn at two revolutions per second. You get out two revolutions per second after having put in four revolutions per second. This means that you get half the speed out of the last driven wheel that you put into the first driver wheel. The formula for gear speed-reduction is given here:

$$S_2 = S_1 \times \frac{T_1}{T_2}$$

S_1 = speed of first shaft in train

S_2 = speed of last shaft in train

T_1 = product of teeth on all drivers

T_2 = product of teeth on all driven gears

By using the formula on the gear train in figure 9, the following solution is found.

$$S_2 = S_1 \times \frac{T_1}{T_2}$$

$$= 4 \times \frac{10 \times 20}{40 \times 10} = \frac{800}{400}$$

$$= 2 \text{ revolutions per second}$$

You can increase or decrease almost any speed by selecting the correct gears for the job. For instance, the turbines on a ship have to run at high speeds to be efficient,

but the propellers must turn much more slowly. To do this, a set of reduction gears is placed between the turbines and the propeller shaft.

If two external gears mesh, they always rotate in opposite directions. Sometimes it is necessary for them to rotate in the same direction. To do this, a third gear, called an **idler**, is added between the driver and the driven gear. This does not change the gear ratio, but merely makes the driver and its driven gear turn in the same direction, as shown in figure 10.

Increasing Force with Gears

A mechanical advantage can be gained if gear trains are used. Any time there is a speed reduction, the effect of the energy you apply is multiplied. A cable winch is shown in figure 11. The crank arm is 30 inches long, and the drum on which the cable is wound has a 15-inch radius. The small pinion gear has 10 teeth, which mesh with the 60 teeth on the internal spur gear. It is easier to calculate the mechanical advantage of this device by considering it as two machines.

The first set of figures will show you how to use the gear and pinion to an advantage. The theoretical mechanical advantage (M.A.) of any arrangement of two meshed gears is figured by using this formula:

$$\text{M. A.} = \frac{T_o}{T_a}$$

Where:

T_o = number of teeth on the driven gear

T_a = number of teeth on driver gear

Solution: $T_o = 60$ and $T_a = 10$

$$\text{M. A.} = \frac{T_o}{T_a} = \frac{60}{10} = 6$$

The other part of the machine is a simple wheel-and-axle arrangement consisting of the crank arm and the drum. The mechanical advantage of this can be found by dividing the distance the effort moves ($2\pi r$) to make one complete revolution, by the distance the cable is drawn up in one revolution of the drum ($2\pi R$). Use the following formula.

$$\text{M.A.} = \frac{2\pi R}{2\pi r} = \frac{R}{r} = \frac{30}{15} = 2$$

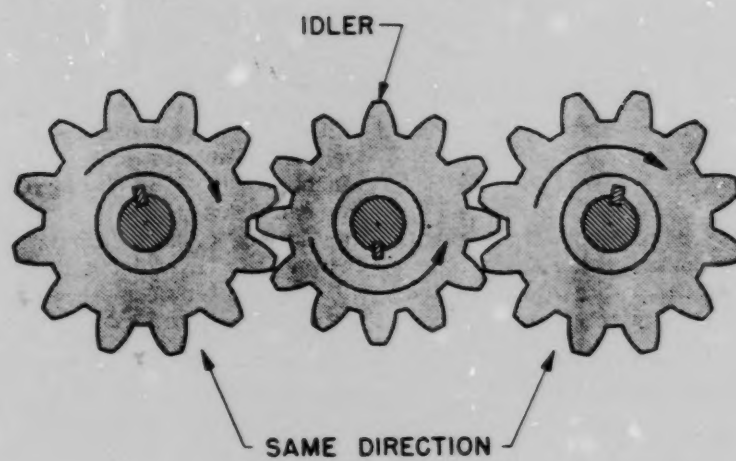


Fig. 10. Idler gear

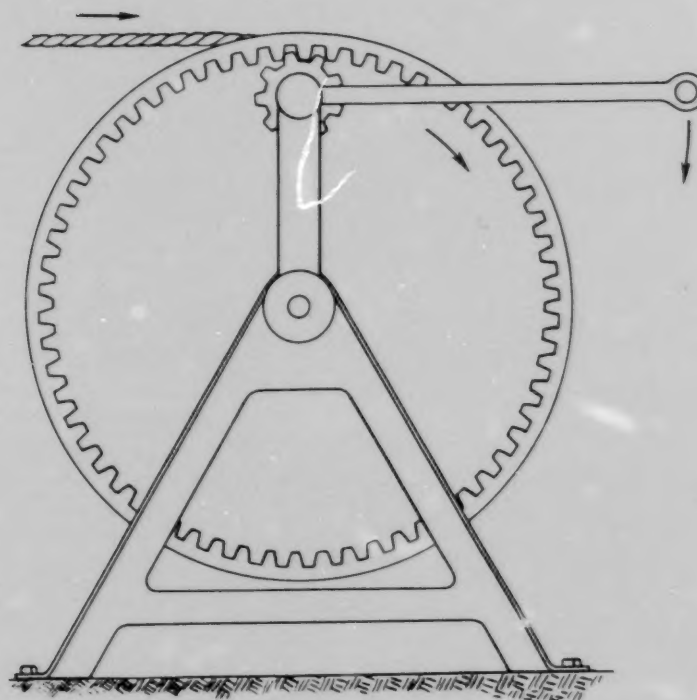


Fig. 11. Using gears for mechanical advantage

The mechanical advantage of a compound machine is equal to the product of the mechanical advantages of several simple machines that make it up. The winch is considered as two simple machines with one having a mechanical advantage (M.A.) of 6, and the other with an M.A. of 2. The overall theoretical mechanical advantage of the winch is 6 times 2, or 12. Since friction must be considered, the actual mechanical advantage may be only 7 or 8. Still, by applying a force of 100 pounds on the handle, you could lift a load of 700 or 800 pounds.

Exercise

1. What is the advantage of using gears rather than a belt drive?
2. Name the three changes that are made by the gears in the egg beater shown in figure 1.
3. What gears can be used to transmit motion from one shaft to another when the shafts are parallel but not lying in the same straight line?
4. When two gears of different sizes are meshed together, what is the smaller gear called?
5. What type of spur gear has teeth that are cut slantwise across the edges of the gear?
6. What is the advantage of the gear mentioned in question 5?
7. What type of bearing is not needed with herringbone gears?
8. Why is a sector gear used?
9. What type of gear is used when shafts are not parallel?
10. How far does a worm turn to cause a worm wheel to turn one tooth?
11. What gear is a combination of a screw and a spur gear?
12. What does a nonreversing worm drive provide?
13. If you turn handle E in figure 8 in a clockwise direction, how does gear F directly above it turn?
14. Give the formula for gear speed-reduction.
15. If two external gears must rotate in the same direction, what gear must be placed between the driver and the driven gear?
16. How is it easier to calculate the mechanical advantage of a device such as the one shown in figure 11?
17. What is the mechanical advantage of a compound machine equal to?

F-2

Belts and Pulleys

Objectives: After completing this assignment, you will be able to—

1. discuss V-belt-drive arrangements;
 2. describe variable-pitch pulleys; and
 3. discuss how pulleys and belts transmit power.
-

Transmitting Power

As a millwright, you will at times need to install or replace belts and pulleys. They are used most often to transmit power from a motor to another piece of equipment. The V-belt gets its name from its triangular or V-shaped cross section, as shown in figure 1. It fits into a V-shaped slot in the pulley. This keeps the belt from jumping off the pulley during operation, as well as preventing it from slipping. Side pressure from the pulley adds the tension necessary to hold the belt to the pulley. Always be careful that the belt fits the pulley. The inside of the belt should never touch the bottom of the groove in the pulley, or you would lose the benefits of the side pressure.

Various V-belt-drive arrangements can be made to transmit the necessary speed to machinery parts. This is done by changing the size of one or both pulleys. One type of arrangement is shown in figure 2. Both pulleys always turn in the same direction. At times a motor must be used in reverse for certain types of machinery. In figure 2, motor pulley A turns at the motor speed, while the larger pulley turns more slowly. Pulley B has a diameter 2 1/2 times that of pulley A, so the speed-reduction is 2.5 to 1. If the procedure is reversed, the speed is increased by the same amount.

Step pulleys are sometimes used on small equipment. This consists of both pulleys having several matching grooves.

When the pulleys are lined up (fig. 3), the large diameter on one pulley matches the small diameter on the other pulley. When speeds must be changed fairly often, it is convenient to simply slip the belt to the grooves that will give the desired speed.

Another arrangement used on large equipment where a great deal of power is needed consists of a multiple arrangement. Each pulley has several grooves, but each groove in a particular pulley has the same diameter. This way several belts may be placed on the pulleys to give more holding power when the added torque from a powerful motor is applied.

Variable-Pitch Pulleys

These types of pulleys are used on equipment where speed changes are needed fairly often, but the change is slight. The pulley has two separate sides, as shown in figure 4. One part is fastened in a permanent position on a shaft. The other half can be moved closer to or further away from the permanent side of the pulley, then fastened to the shaft with a setscrew. This allows a belt to fall deeper into the V-groove or to move further up. This, in turn, changes the diameter of the pulley to attain the desired change. When this adjustment is made, do not forget to adjust the tension of the belt. Either loose belts or tight belts can damage the belt or pulleys, as well as injure the operator.

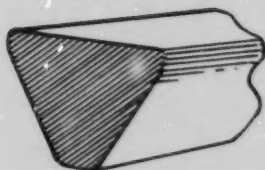


Fig. 1. Cross section of V-belt

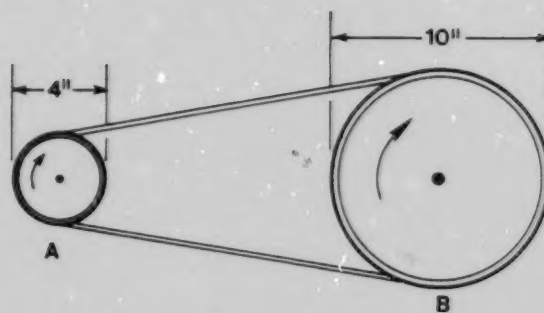


Fig. 2. Transmitting speeds by belt and pulleys



Fig. 3. Step pulleys

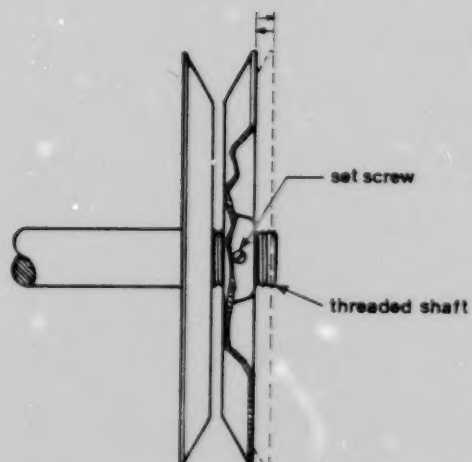


Fig. 4. Variable-pitch pulley

Always see that the power is off before changing or making adjustments to belts and pulleys. Be sure the belt is running true in the pulley groove to keep the belt from being thrown off. Never place your hands near these parts when the equipment is running. Keep oil and grease off all belts or slippage will occur.

Exercise

1. Where do belts and pulleys most often transmit power from?
2. Where does the V-belt get its name?
3. Why should the inside of a belt not touch the bottom groove in the pulley?
4. What type of pulley is sometimes used on small equipment?
5. When are several belts used on multiple pulleys?
6. When are variable-pitch pulleys used?
7. How is the diameter of a variable-pitch pulley changed?
8. Why should oil and grease be kept off all belts?

F-3

Bearings and Springs

Objectives: After completing this assignment, you will be able to—

1. discuss the methods used to overcome friction;
 2. give the types and uses of various bearings; and
 3. identify various types of springs and their functions.
-

Friction

Friction is the resistance to any force that causes motion of one surface over another. This means that if any object is rubbed against another object, friction is caused. If the surface or surfaces are smooth, less friction is produced and the object slides more easily. Even pushing an object on wheels against a floor (static friction) is harder until movement has started. Rolling friction is always less than sliding friction; therefore, you should always take advantage of this fact. Also, lubricants on rubbing surfaces lessen the amount of friction that takes place.

Bearings

A bearing is a support and guide that carries a moving part or parts of a machine and keeps the proper relationship between the moving part or parts and a permanent base. It normally allows only one form of motion, such as rotation, and prevents any other motion.

There are two primary types of bearings: (1) sliding type or sleeve (plain bearings), sometimes called friction or guide bearings, and (2) antifrictional type (roller and ball bearings).

Sliding or Sleeve Type (Plain). Remember that a film of lubricant is always used between the moving part and the permanent

part. The three types of sliding motion bearings commonly used are reciprocal motion bearings, journal bearings, and thrust bearings.

Reciprocal motion bearings give a bearing surface on which an object slides back and forth. They are used on steam reciprocating pumps, where connecting rods slide on bearing surfaces near their connections to the pistons. Bearings similar to these are also used on the connecting rods of large internal-combustion engines and other machinery operated by cams.

Journal bearings are used to guide and support revolving shafts. The shaft revolves in a housing fitted with a liner. The inside of the liner, on which the shaft bears, is made of babbitt metal or other soft alloy to reduce friction. The soft metal is backed by a bronze or a copper layer and has a steel backing to add strength. Sometimes the bearing is made in two parts and is clamped or screwed around the shaft (fig. 1). It is sometimes called a **laminated sleeve bearing**.

Under most conditions, the friction in journal bearings is very small. If the rubbing speed of a journal bearing is very low or extremely high, there may be friction problems.

Heavy-duty bearings have oil circulated around and through them. Some have cooling systems consisting of water jackets near the bearings that contain circulating water.

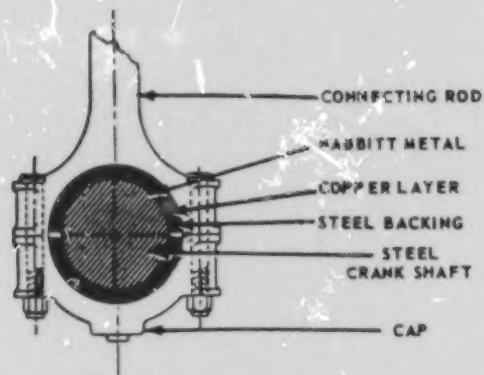


Fig. 1. Journal bearing

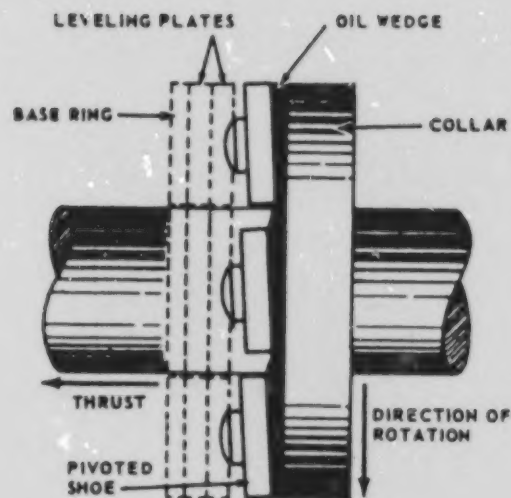
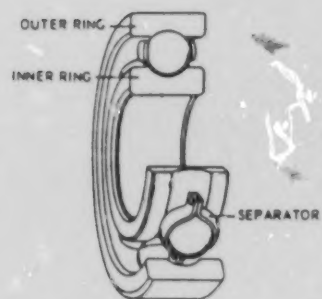
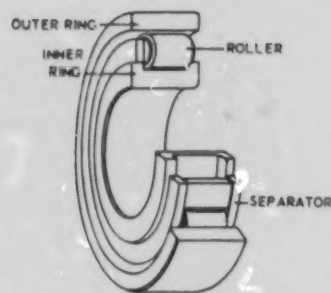


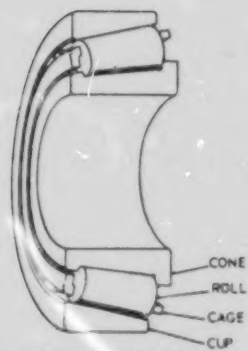
Fig. 2. Thrust bearing



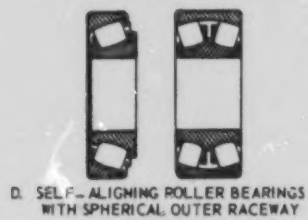
A. RADIAL BALL BEARINGS



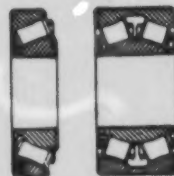
B. CYLINDRICAL ROLLER BEARINGS



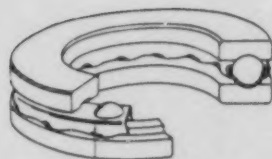
C. TAPERED ROLLER BEARINGS



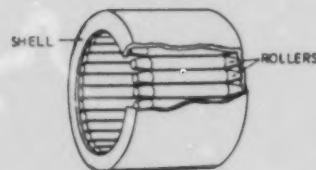
D. SELF-ALIGNING ROLLER BEARINGS
WITH SPHERICAL OUTER RACEWAY



E. SELF-ALIGNING ROLLER BEARINGS
WITH SPHERICAL INNER RACEWAY



F. BALL THRUST BEARINGS



G. NEEDLE ROLLER BEARINGS

Fig. 3. Antifrictional bearings

Thrust bearings are used on rotating shafts, such as those supporting bevel gears, worm gears, propellers, and fans. They are installed to resist axial thrust or force and to limit axial movement. They are used mostly on heavy machinery. The base of the housing holds an oil bath, and the rotation of the shaft continually distributes the oil. The bearing (fig. 2) consists of a thrust collar on the shaft and two or more stationary thrust shoes on either side of the collar. Thrust is transmitted from the collar through the shoes to the gear housing and the machine's structure to which the gear housing is bolted.

Antifrictional Type (Roller and Ball). You are probably familiar with ball bearings, as they are found in many mechanical devices, such as wheels on roller skates. The balls or rollers are made of hard, highly polished steel. The typical bearing consists of two hardened steel rings (races), a number of steel balls or rollers, and a separator. The turning motion takes place between the race surfaces and the rolling elements. The seven basic types of antifrictional bearings, listed below, are shown in figure 3.

1. Radial ball bearings
2. Cylindrical roller bearings
3. Ball thrust bearings
4. Needle roller bearings
5. Tapered roller bearings
6. Self-aligning roller bearings with spherical outer raceway
7. Self-aligning roller bearings with spherical inner raceway

Roller bearing assemblies are usually easy to disassemble for inspection, cleaning, and replacement of parts. Ball bearings, however, are assembled at the factory and the whole unit must be replaced. Sometimes roller and ball bearings are referred to as being either thrust or radial bearings. The difference between the two depends on the angle of intersection between the direction of the load and the plane of rotation of the bearing.

A **radial ball bearing** assembly is shown in figure 4A. The load is pressing outward along the radius of the shaft. If a strong thrust is exerted on the right end of the shaft, it tends to move to the left. Therefore, the radial bearing will not support this axial thrust. This type of load usually pops the bearings out of their races. A **thrust bearing** (fig. 4B) is used to eliminate this

problem. With a shoulder under the lower race, and another between the load and the upper race, it will handle any axial load up to its design limit. Radial thrust bearings are also made to support both thrust and radial loads.

Antifriction bearings require smaller housings than other bearings of the same load capacity and can operate at higher speeds.

Springs

At times you may have to install or replace springs in various pieces of equipment. Springs are elastic devices, usually made of metal, that can be stretched, twisted, or pulled by some force, then can return to their original shape when the force is released. Most springs are made of steel, but other materials or alloys can be used. If a part is under constant spring-thrust or pressure, it is said to be "springloaded."

Purposes of Springs. Springs serve one or more of these purposes:

1. To maintain electrical continuity
2. To store energy for part of a functioning cycle
3. To return a component to its original position after displacement
4. To force a component to bear against, to maintain contact with, to engage, to disengage, or to remain clear of some other component
5. To reduce shock or impact by gradually checking the motion of a moving weight
6. To counterbalance a weight or thrust (equilibrator springs)
7. To permit some freedom of movement between aligned components without disengaging them (takeup springs)

Types of Springs. Three basic types of springs are used in most pieces of equipment. They are the flat, spiral, and helical or coil. **Flat springs** (fig. 5A (1) and (2)) are made up of flat or slightly curved bars, plates, or leaves. Special flat springs, shown in figure 5A (3), are made from a flat strip or bar into whatever shape or design is needed for their position and purpose.

Spiral springs are sometimes called clock or power springs. An example is

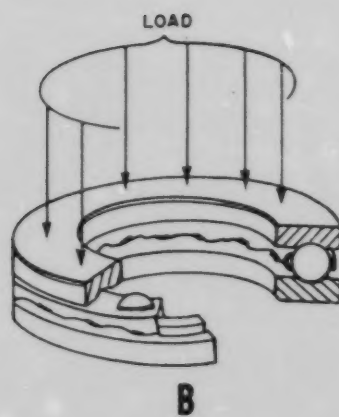
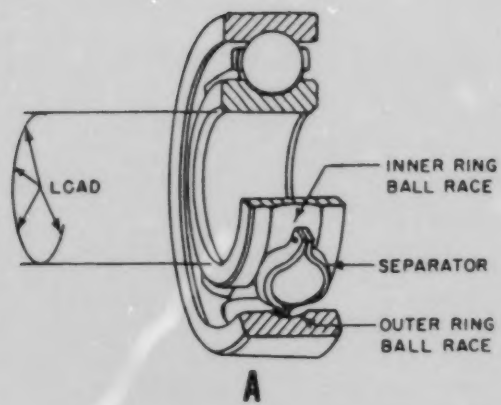


Fig. 4. Ball bearings: (A) radial type; (B) thrust type



(1) ELLIPTIC OR LEAF

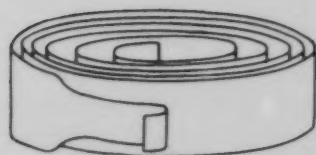


(2) HALF-ELLIPTIC LEAF

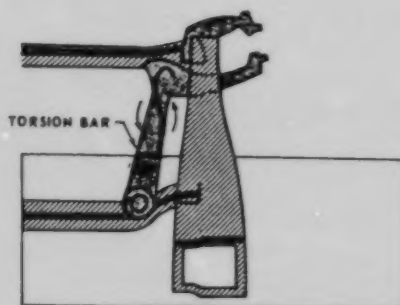


(3) SPECIAL FLAT

A FLAT SPRINGS



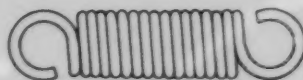
B SPIRAL SPRING



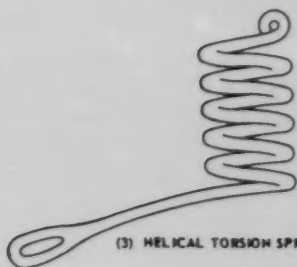
C TORSION BARS



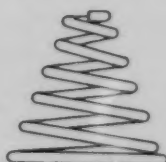
(1) HELICAL COMPRESSION SPRING



(2) HELICAL TENSION SPRING



(3) HELICAL TORSION SPRING



(4) HELICAL CONE OR VALVE SPRING



(5) VOLUTE SPRING

D HELICAL OR COIL SPRINGS

Fig. 5. Types of springs

shown in figure 5B. It is wound or tightened, then gradually releases the tension as it unwinds.

Helical springs (fig. 5D) are probably the most common type of spring. A spring used in compression (fig. 5D (1)) tends to shorten in action, while a tension spring (fig. 5D (2)) lengthens in action. Torsion springs (fig. 5D (3)) are made to transmit a twist instead of a direct pull, and operate by a coiling or uncoiling action.

Cone, double cone, keg, and volute springs are also classed as helical. They are usually used in compression. A cone spring (fig. 5D (4)), often called a valve spring because it is frequently used in valves, is shaped by winding the wire on a tapered mandrel instead of a straight one. A double cone spring is composed of two cones joined at their small ends, while a keg spring is two cone springs joined at their large ends.

Volute springs (fig. 5D (5)) are conical springs made from a flat bar that is wound so that each coil partially overlaps the one next to it.

Torsion bars (fig. 5C) are straight bars that are acted on by torsion (twisting force). The bar may be circular or rectangular in cross section.

Exercise

1. Give the definition for **friction**.
2. What type of friction is always less than sliding friction?
3. Name the two primary types of bearings.
4. Name the three common types of sliding motion bearings.
5. What do journal bearings guide and support?
6. What happens if the rubbing speed of a journal bearing is very low or extremely high?
7. Why are thrust bearings installed?
8. What are the parts of a typical antifrictional bearing?
9. Which antifrictional bearing assembly is usually easy to disassemble for inspection, cleaning, and replacement of parts?
10. What does it mean if a part is said to be "springloaded"?
11. Name the three basic types of springs used in most pieces of equipment.
12. What are probably the most common types of springs?
13. What type of spring lengthens in action?

F-4

Hydraulics

Objectives: After completing this assignment, you will be able to—

1. discuss how liquids are used to move equipment parts;
 2. give the principles used in hydraulic machines;
 3. give the method for figuring hydraulic pressures; and
 4. describe the use of an accumulator.
-

Liquids for Movement

A simple example of hydraulics in operation is the lifting of an automobile on a grease rack at a service station. Hydraulic fluid under pressure below the piston pushes upward to lift the weight of the vehicle. A hydraulic jack works on the same principle.

Primitive people used simple machines, such as the lever, the inclined plane, the pulley, the wedge, and the wheel and axle. Later it was discovered that liquids and gases could be used to exert forces at a distance. A machine that transmits forces by means of a liquid is a hydraulic machine. If the machine is operated by the use of compressed gas, it is called a pneumatic machine.

Hydraulic Principle

A Frenchman named Pascal discovered that a pressure applied to any part of a confined fluid is transmitted to every other part with no loss. The pressure acts with equal force on all equal areas of the confining walls, and perpendicular to the walls. Liquids differ from air in that most liquids cannot be compressed into a smaller space, but air will "give" under enough pressure.

An example of hydraulic pressure is shown when you punch a hole in a tube of toothpaste. If you push down at any point

on the tube, the paste comes out of the hole. The force has been transmitted from one place to another by the paste, which is a thick fluid. Figure 1 shows what would happen if you punched four holes in the tube. If you press on the tube at any point, the paste comes out of all four holes. This means that a force applied on a liquid (or paste in this case) is transmitted equally in every direction to all parts of the container.

The same principle is used in the operation of hydraulic automobile brakes. When you push down on the brake pedal, the piston in the master cylinder is forced against the fluid. The pressure is then transmitted through the lines to the brake cylinders in each wheel. The piston in each of the brake cylinders forces the brake shoes out to rub against the drums to slow the progress of the vehicle.

Mechanical Advantages

In order to understand hydraulic machines, you should know the relationship between the force that is applied and the result to expect. The U-shaped tube in figure 2 has a cross-sectional area of 1 square inch. In each arm is a piston that fits snugly, but is capable of moving up and down. If you insert a 1-pound weight on one piston, the other will be pushed out the top of the tube. If a 1-pound weight is placed on each piston,



Fig. 1. Pressure is transmitted in all directions.

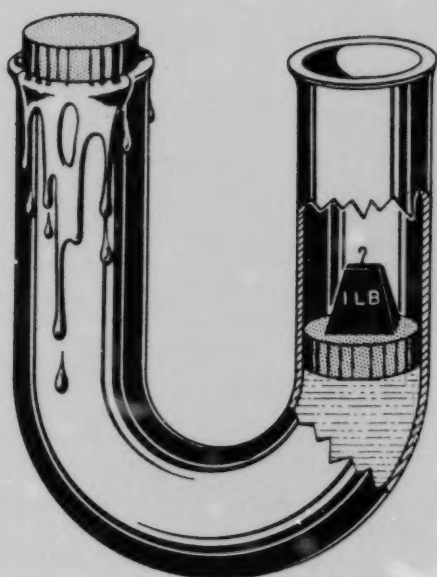


Fig. 2. Transmitting force with liquid

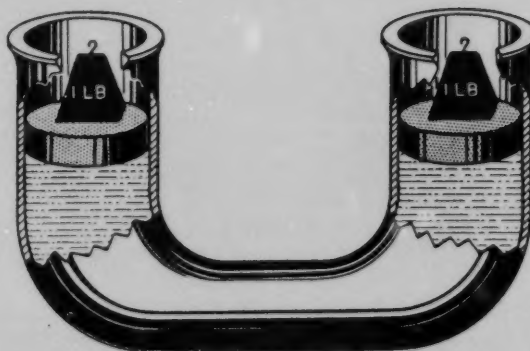


Fig. 3. Equal pressure on all parts of an enclosed liquid

they will both remain in a fixed position, as shown in figure 3.

This means that a pressure of 1 pound per square inch applied downward on the right-hand piston exerts a pressure of 1 pound per square inch upward against the left-hand one. The force is transmitted by the liquid around the curve and the force is the same on each unit area of the tube. It makes no difference how long the connecting tube is, or how many turns it makes. However, the entire tube must be full of liquid. Hydraulic systems will fail to operate properly if any air is present in the lines or cylinders.

The device shown in figure 4 illustrates how mechanical advantage is created. The piston on the right has an area of 1 square inch, but the piston on the left has an area of 10 square inches. If you push down on the smaller piston with a force of 1 pound, the liquid transmits this pressure to every square inch of surface in the system. Since the left-hand piston has an area of 10 square inches, and each square inch has a force of 1 pound transmitted to it, the total effect is to push on the larger piston with a total force of 10 pounds. If you set a 10-pound weight on the larger piston, it will be supported by the 1-pound force of the smaller piston. This gives a mechanical advantage of ten. This is why hydraulic machines are so important.

Figuring Hydraulic Pressures

The formula for figuring forces that are created by hydraulic machines is given below.

$$\frac{F_1}{F_2} = \frac{A_1}{A_2}$$

Where:

F_1 = force, in pounds, applied to the small piston

F_2 = force, in pounds, applied to the large piston

A_1 = area of the small piston, in square inches

A_2 = area of the large piston, in square inches

Use this formula on the hydraulic press in figure 5. The large piston has an area of 90 square inches and the smaller one an area of 2 square inches. The handle exerts a total force of 15 pounds on the small piston. With what total force will the large piston be raised?

Use the formula given and substitute the known values.

$$\frac{15}{F_2} = \frac{2}{90} \quad F_2 = \frac{90 \times 15}{2} = 675 \text{ pounds}$$

This is not quite all there is to the problem. You know that you cannot get a 10-pound force from a 1-pound effort without sacrificing distance. The 1-pound effort will have to be applied through a much greater distance than the 10-pound force will move. If you raise the 10-pound weight through a distance of 1 foot, through what distance will the 1-pound effort have to be applied?

At this point we have to remember that work input equals work output. The formula simply states that work = force X distance. By substituting "force times distance" on each side of a work equation, you have the following formula:

$$F_1 \times D_1 = F_2 \times D_2$$

$$\text{Solution: } 1 \times D_1 = 10 \times 1$$

$$D_1 = 10 \text{ feet}$$

This leaves a small problem. The smaller piston will have to move through a distance of 10 feet in order to raise the 10-pound load 1 foot. It looks as if the smaller cylinder would have to be at least 10 feet long, which is not practical. To overcome this problem, a valve is placed in the system.

The hydraulic press in figure 5 contains a valve for this purpose. As the small piston moves down, it forces the fluid past the check valve into the large cylinder. As soon as you start to move the small piston upward, the pressure to the right of the check valve is removed, and the pressure of the fluid below the large piston helps the check valve spring force that valve shut. The liquid which has passed through the valve opening on the downstroke of the small piston is trapped in the large cylinder.

The small piston rises on the upstroke until its bottom passes the opening to the fluid reservoir. More fluid is sucked past a check valve and into the small cylinder. The next downstroke forces this new charge of fluid out of the small cylinder past the check valve into the large cylinder. This process is repeated stroke by stroke until enough fluid has been forced into the large cylinder to raise the large piston the required distance of 1 foot. The force has been applied through a distance of 10 feet

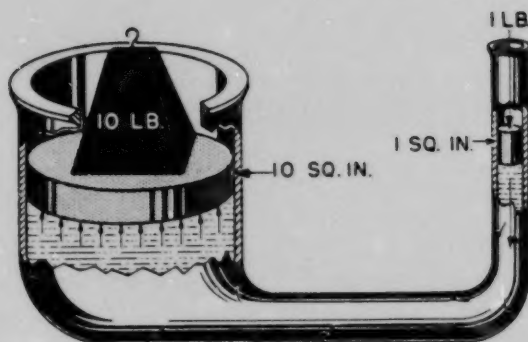


Fig. 4. Creating a mechanical advantage of 10

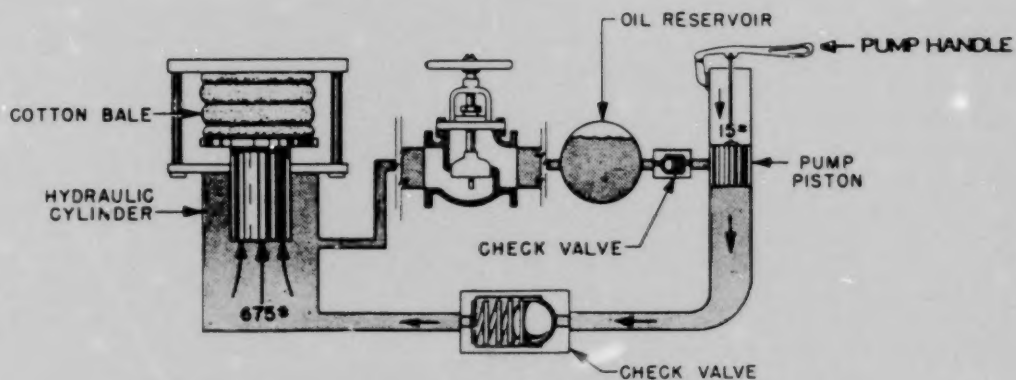


Fig. 5. Hydraulic press

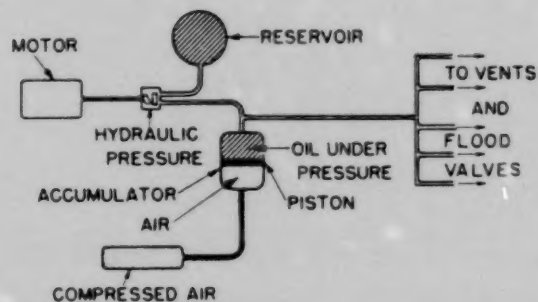


Fig. 6. Using an accumulator for fluid storage

on the pump handle, but it was done by making a series of relatively short strokes.

You must get the large piston back down after you have baled the cotton in the example used. The fluid cannot run back past the check valve at the bottom of the drawing, so you lower the piston by letting the fluid flow back to the reservoir through a return line. Notice that a simple gate valve is inserted in this line. When the gate valve is opened, the fluid flows back into the reservoir. This valve must be kept shut while the pump is in operation.

Accumulators

In some hydraulic systems, hydraulic fluid is kept under pressure in a container called an accumulator. Figure 6 illustrates this large cylinder, into the top of which the fluid is pumped. A free piston divides the cylinder into two parts. Compressed air is forced in below the piston at a high pressure. The fluid is then forced in on top of the piston. As the pressure above it increases, the piston is forced down, and squeezes the air into a smaller space. The air compresses under pressure, but expands as soon as the pressure is reduced. When fluid pressure is reduced, relatively large quantities of fluid under working pressure are instantly avail-

able to operate any hydraulic machines that are needed.

Exercise

1. What is a machine called that transmits forces by means of a liquid?
2. What did Pascal discover about fluid pressure?
3. How does liquid pressure differ from air pressure?
4. What two conditions could cause a hydraulic system to work improperly?
5. What is the mechanical advantage of the device in figure 4?
6. What is the formula used for figuring forces created by hydraulic machines?
7. What does F_1 represent in the formula?
8. If you are trying to get a 10-pound force from a 1-pound effort, what do you sacrifice?
9. What does work input equal?
10. What device is used to compensate for the distance the hydraulic fluid must move?
11. How do you get a piston back down after it has been moved upward by the force of hydraulic fluid?
12. What is the container called that keeps hydraulic fluid under pressure?
13. What is used to force fluid on top of a piston in an accumulator?

F-5

Block and Tackle

Objectives: After completing this assignment, you will be able to—

1. describe the various types of blocks and tackles;
 2. explain the mechanical advantages of using blocks and tackles;
 3. discuss the use of chain hoists; and
 4. give the various applications of blocks and tackles.
-

In your work you will often rig a block and tackle to make lifting much easier. A block is really a pulley and is shown with labeled parts in figure 1. If you fasten a single block to a fixed object, you give yourself the advantage of being able to pull from a convenient direction.

Mechanical Advantage

When you use a single fixed sheave, the force of your down-pull must be equal to the weight of the object being hoisted. You cannot use this rig to lift a heavy load or resistance with a small effort. You can change only the direction of your pull.

A single fixed block is really a first-class lever with equal arms. The arms EF and FR in figure 2 are equal, so the mechanical advantage is one. When you pull down at A with a force of 1 pound, you raise a load of 1 pound at B. A single fixed block does not add force or speed. However, there is a way to use a single block and tackle to magnify the force you exert. Notice that in figure 3 the block is not fixed, but the rope is doubled as it supports the 200-pound cask. When it is rigged this way, a single block and tackle is called a **runner**. Each half of the rope (tackle) carries one half of the total load, or 100 pounds. By using the runner, the person is

lifting a 200-pound cask with a 100-pound pull. The mechanical advantage is two. The formula is that mechanical advantage (M.A.) equals resistance (R) divided by effort (E), as shown here:

$$M. A. = \frac{R}{E} = \frac{200}{100} = 2$$

The single movable block in figure 4 is really a second-class lever. Your effort (E) acts upward upon the arm EF, which is the diameter of the sheave. The resistance (R) acts downward on the arm FR, which is the radius of the sheave. Since the diameter is twice the radius, the mechanical advantage is two.

When the effort at E moves up 2 feet, the load at R is raised only 1 foot. If you are actually getting a mechanical advantage from a block and tackle system, the length of rope that passes through your hands is always greater than the distance the load is raised. Of course if you can lift a large load with a small effort, how much rope you must pull is not too important.

The person in figure 3 is in an awkward position to pull. If another single block is used (fig. 5), the direction of the pull can be changed. This is known as a **gun tackle purchase**. Because the second block is fixed, it only changes the direction of pull. The mechanical advantage is still two.

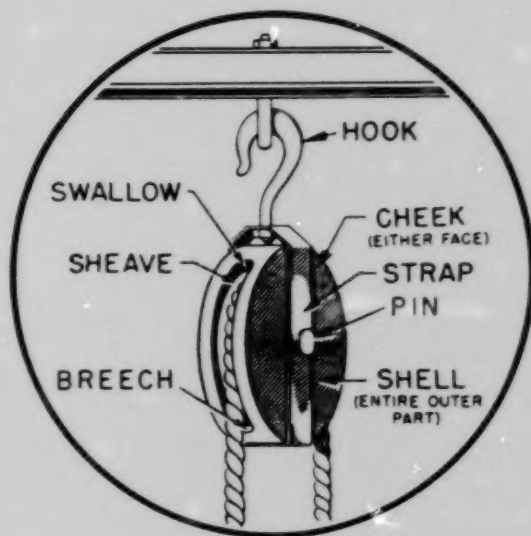


Fig. 1. Parts of a block (pulley)

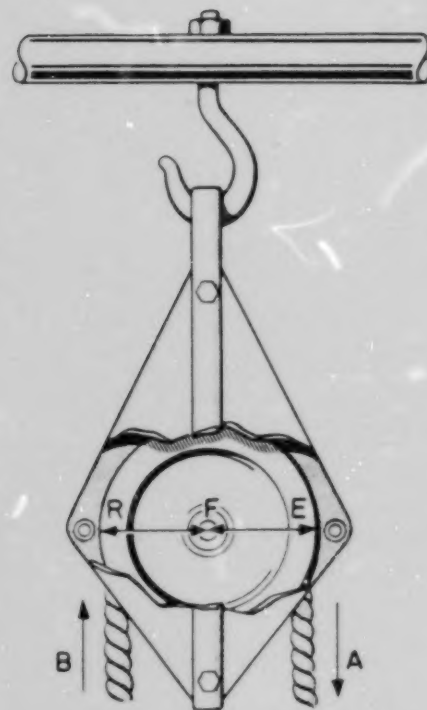


Fig. 2. Single fixed block

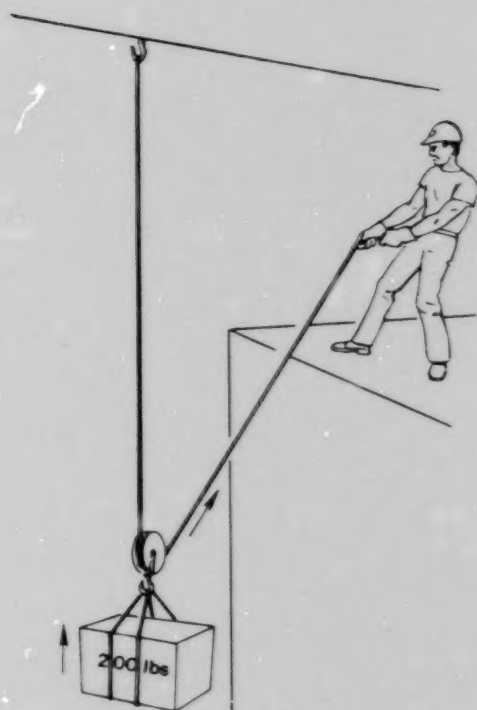


Fig. 3. Runner block and tackle

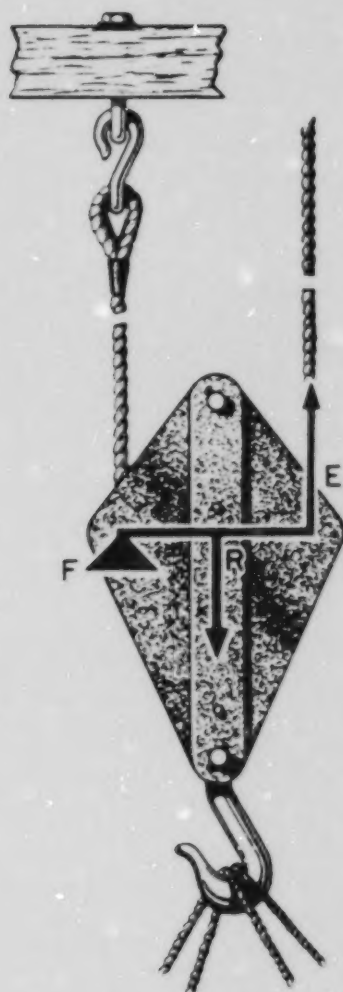


Fig. 4. Single movable block acting as a second-class lever

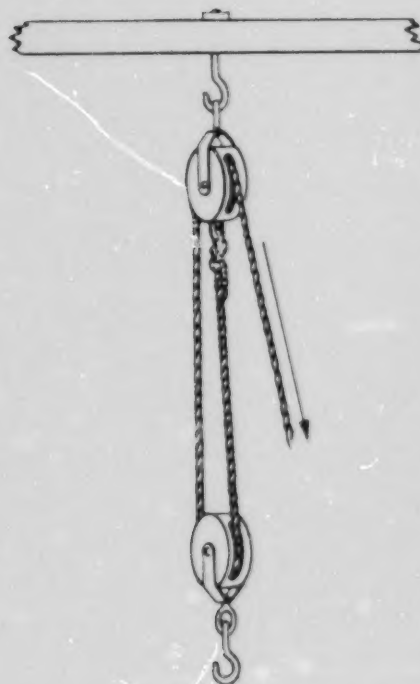


Fig. 5. Gun tackle

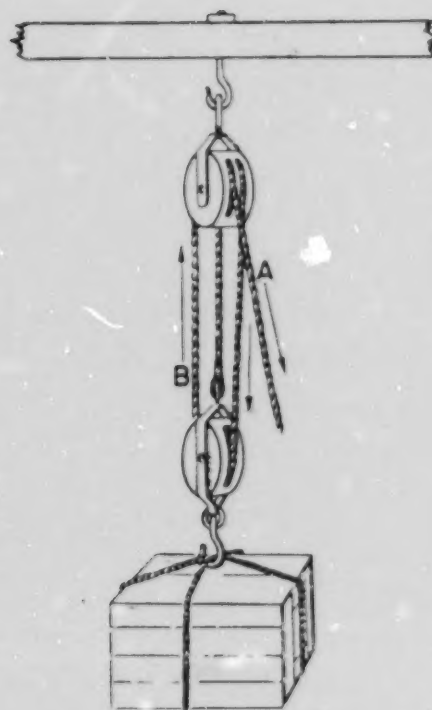


Fig. 6. Luff tackle

Blocks can be arranged in a number of ways to do a certain job or to gain the mechanical advantage you desire. A **luff tackle** (fig. 6) consists of both a double block and a single block. The weight is suspended by three parts of rope which extend from a movable single block. Each part of the rope carries its share of the load. If the crate weighs 600 pounds, each of the three parts of the rope supports 200 pounds. If there is a pull of 200 pounds downward on rope B, you have to pull downward with a force of 200 pounds on A to counterbalance the pull on B. After discounting the friction in the block, a pull of 200 pounds is all that is necessary to raise the crate. The mechanical advantage is shown in this formula:

$$M. A. = \frac{R}{E} = \frac{600}{200} = 3$$

If you count the number of the parts of rope going to and from the movable block, you can figure the mechanical advantage at a glance. There are many possible combinations of single, double, and triple sheave blocks. Two of these combinations are shown in figure 7.

An important point to remember is that the strength of the rope is a limiting factor in any tackle. Be sure it is strong enough to carry the load. There is no point in rigging a sixfold purchase to carry a 5-ton load with two triple blocks on a 3-inch manila rope attached to a winch. The winch could withstand the load, but the rope could not.

Lifting Applications

Blocks and tackles are used for a great number of lifting and moving jobs when you are installing or moving heavy equipment. The five or six basic combinations are used over and over again in many situations. Heavy machinery can easily be swung into position with the aid of blocks and tackles. **Yard and stay tackles** are used to pick up heavy machine parts and swing them onto the primary machine or to shift a load a short distance. Figure 8 shows you how the load is first picked up by the yard tackle. The stay tackle is left slack. After the load is raised to the height necessary to clear obstructions, you take up on the stay tackle and ease off on the yard rope. A glance at the rig tells you that the mechanical advantage

of each of these tackles is only two. You may think it is not worth the trouble to rig a yard and stay tackle with that small an M.A. just to move a 400-pound object along the floor. However, a few minutes spent in rigging may save strains or other more serious injuries.

If you need a high mechanical advantage, a **luff upon luff** is a good rig to use. You can lift heavy loads with this setup. Figure 9 shows how this combination is rigged. If you apply the rule by which you count the parts of the rope going to and from the movable blocks, you can see that block A gives a mechanical advantage of 3 to 1. Block B has four parts of rope running to and from it, with a mechanical advantage of 4 to 1. The mechanical advantage obtained from A is multiplied four times in B. The overall mechanical advantage of a luff upon luff is the product of the two mechanical advantages, or 12. Be sure you do not make the mistake of adding mechanical advantages. Always multiply them.

Chain Hoists

In many shops or plants you may be able to use a chain hoist, or differential pulley. These hoists are usually suspended from overhead trolleys and are used to lift heavy objects and move them from one part of the building to another.

To help you understand the operation of a chain hoist, look at the one in figure 10. Assume that you grasp the chain at E and pull until the large wheel A has turned around once. Then the distance through which your effort has moved is equal to the circumference of that wheel, or $2\pi R$. Since wheel C is a single movable block, its center is raised only one-half the distance that the chain E was pulled, or a distance πR . However, the smaller wheel B, which is rigidly fixed to A, makes one revolution at the same time as A does, so B will feed some chain down to C. The length of the chain fed down is equal to the circumference of B, or $2\pi r$. Again, since C is a single movable block, the downward movement of its center is equal to only one-half the length of the chain fed to it, or πr .

Of course, C does not first move up a distance πR and then move down a distance πr . Actually, its steady movement upward is equal to the difference between the two,

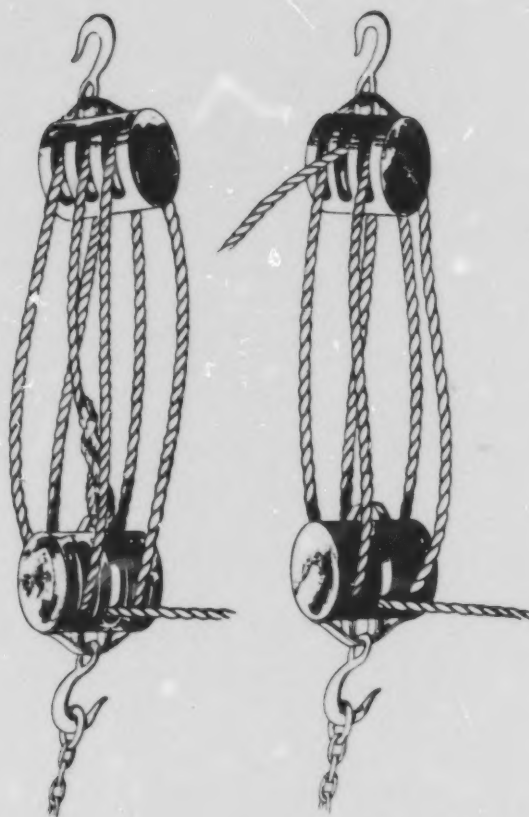


Fig. 7. Examples of sheave blocks

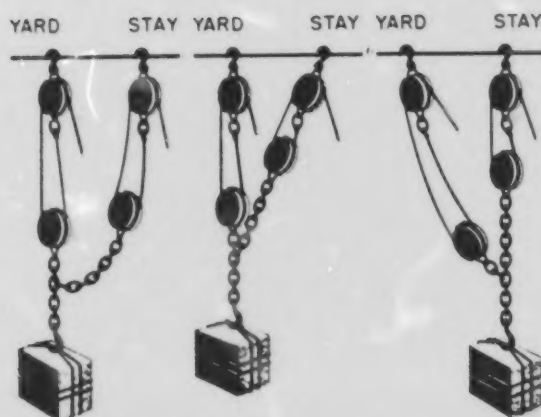


Fig. 8. Yard and stay tackles

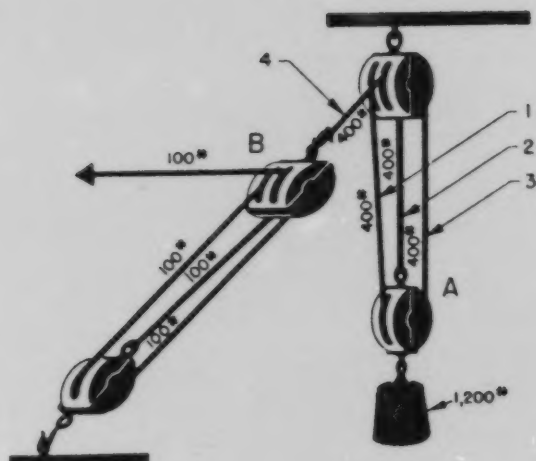


Fig. 9. Luff upon luff tackle

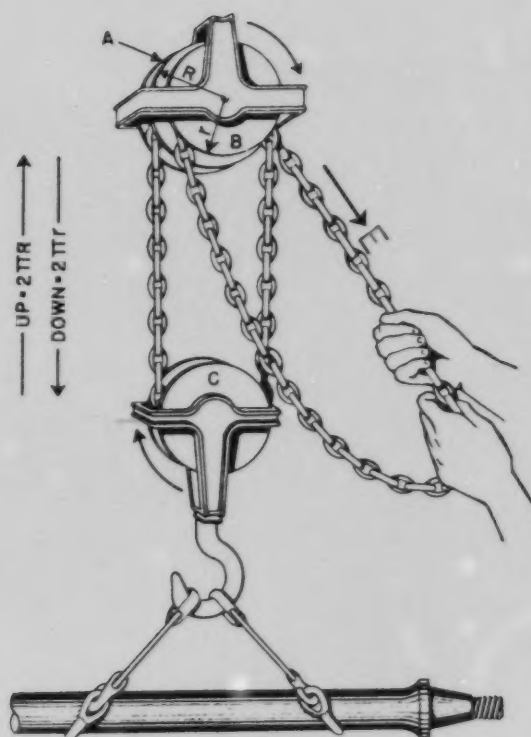


Fig. 10. Chain hoist

or $\pi R - \pi r$. The size of the movable pulley, C, is not important. It does not enter into these calculations. Its diameter is usually between that of A and that of B.

The mechanical advantage equals the distance through which the effort E is moved, divided by the distance that the load is moved. This is called the velocity ratio, or theoretical mechanical advantage. It is theoretical because the frictional resistance to the movement of mechanical parts is left out. Realistically, all moving parts have some frictional resistance.

The formula for theoretical mechanical advantage is that theoretical mechanical advantage equals the distance the effort moves divided by the distance the resistance moves, or in this case:

$$\text{T.M.A.} = \frac{2\pi R}{\pi R - \pi r} = \frac{2R}{(R - r)}$$

If A is a large wheel, and B is a little smaller, the value of $2R$ becomes large, and $(R - r)$ becomes small. Then you have a large number for $2R/(R - r)$, which is the theoretical mechanical advantage.

You can lift heavy loads with chain hoists. To give you an idea of the mechanical advantage of a chain hoist, suppose the large wheel has a radius (R) of 6 inches and the smaller wheel a radius (r) of $5 \frac{3}{4}$ inches. Use this formula to find the theoretical mechanical advantage:

$$\text{T.M.A.} = \frac{2R}{(R - r)}$$

$$\text{T.M.A.} = \frac{2 \times 6}{6 - 5 \frac{3}{4}} = \frac{12}{\frac{1}{4}} = 48$$

Since the friction in this type of machine is considerable, the actual mechanical advantage is not as high as the theoretical mechanical advantage would lead you to believe. For example, a theoretical mechanical advantage of 48 indicates that with a 1-pound pull, you should be able to lift a 48-pound load. However, a 1-pound pull might only lift a 20-pound load. The rest of your effort would go toward overcoming the friction.

Exercise

1. What is another name for a block?
2. When you use a single fixed sheave, what must the force of your down-pull be equal to?
3. What type of block does not add force or speed?
4. How can you tell if you are getting a mechanical advantage from a block and tackle system?
5. What kinds of blocks are found on a luff tackle?
6. What can you count to figure the mechanical advantage of a block and tackle system?
7. What is the limiting factor in any tackle?
8. What type of rig gives a high mechanical advantage?
9. Where are hoists often suspended?
10. Give the word formula for the theoretical mechanical advantage of chain hoists.
11. What may cause the actual mechanical advantage of a chain hoist to be less than is indicated by the theoretical mechanical advantage?

G-1

Foundations and Platforms

Objectives: After completing this assignment, you will be able to—

1. discuss the use of concrete slabs for heavy equipment;
2. describe the use of joists and floor frames; and
3. discuss types of decking used for equipment support.

Quite often millwrights must build foundations and platforms to support the weight of heavy machinery or machinery parts. This requires some knowledge of structural loads and stresses that may occur from the movements of certain pieces of equipment. For instance, heavy punches or metal fabricators have such a great impact that thick concrete slabs must be poured to withstand the compressive forces and vibrations that occur. These structures may be constructed independently, rather than as a floor or slab for the entire building.

Concrete Slabs

The easiest way to construct a concrete slab is to pour it directly on the ground. It is usually reinforced with either welded wire mesh or reinforcement rods. A form must be built first to hold the concrete in place until it has dried. This form is usually built from heavy plywood sheets and secured to withstand side pressure from the weight of the wet concrete. Although concrete may be mixed on the job, most concrete trucks have long spouts to transport the concrete to the forms. Sometimes deep slabs will require steps to give the worker access to the machine.

Often bolts are inserted in the concrete after it has been poured so the machines or deck plates can be fastened to the slab. The slab should be level and smooth since most

machines must be installed in a level position.

Joists for Support

Some machines are supported on steel or wood joists. They may be installed on bearing walls, on girders, or directly on a concrete slab. Utility lines, such as water, electricity, and oil, may be placed in the spaces between a deck and a slab. Holes may be drilled through the joists to pass lines from the source to the machine.

Floor Frames

Many heavyweight machines will rest on structural steel floor frames. Several workers are needed to install these heavy frames, though often small cranes or hoists are used to install them in place. These units are fastened with bolts, welds, or both.

Decking

The type of material used for decking depends on the type of machine and its weight. Plywood may be used for lightweight equipment, but heavy timbers may be used for heavier equipment. This material is usually bolted to the framing.

Steel decking may be either the ribbed-steel type or the cellular-steel type. The

steel sections can be handled fairly easily as they are not unusually heavy. They are usually screwed or welded in place.

Some machines are equipped with individual stands, bases, or platforms. You will be required to bolt them to the floor. Be sure that all units are leveled and fasteners tightened to eliminate any vibration.

Exercise

1. Why must thick concrete slabs sometimes be poured for certain pieces of equipment?
2. What is the easiest way to construct a concrete slab?

3. What must be constructed to hold a concrete slab in place until it has dried?
4. What is used to reinforce concrete slabs?
5. What may be inserted into the concrete as fastening devices for machines?
6. On what assemblies are steel or wood joists supported?
7. What may be placed in the spaces between a deck and a slab?
8. How are structural steel floor frames fastened?
9. Name the two types of steel decking that may be used beneath machines.
10. How is steel decking fastened?
11. What should you do to help eliminate any machine vibration?

G-2

Welding

Objectives: After completing this assignment, you will be able to—

1. discuss oxyacetylene welding processes;
 2. discuss electric welding operations;
 3. describe the use of resistance (spot) welders; and
 4. give safety precautions to use when welding.
-

Welding and brazing is considered a trade within itself, but the millwright often must use this process of fastening metal materials.

Oxyacetylene Welding and Brazing

This method of welding is divided into welding, brazing, and silver soldering. In oxyacetylene welding, mild steel welding rods are used for most jobs. These rods are usually coated with copper to prevent rust. They vary in size from 1/16 inch to 1/4 inch in diameter and are usually 30 or 36 inches long. No flux is required. The base plates or pieces of steel are brought up to a melting temperature. Then the rod is melted and applied to make a bead and fasten the pieces or parts together.

In brazing, bronze or brass rods of the same size as the steel rods are used. In the brazing process, the base metal is not melted, but merely brought up to a heat that will bond the brass or bronze rod, which melts at a much lower temperature. A flux must be used in this process to make the brass stick to the steel plate or sheet metal. The flux is usually a dry powder or granular type. These are available from different manufacturers.

Silver soldering or silver brazing is very similar to ordinary brazing except that a special alloy containing silver, among other

ingredients, is used. It is one of the strongest methods of fastening thin metal together. When properly done, the silver solder joint is even stronger than the other metal on either side of the joint. Silver solder comes in small flat sticks about 1/16-inch wide. It is very expensive, so too much practicing with this process is impractical. A special flux is required in the silver soldering process. It is usually in a liquid or semiliquid form. Some of it comes in a powder form and is mixed with water as needed.

Electric Welding

Electric welding is used quite often by millwrights. It is divided into three general categories: (1) arc, (2) resistance, and (3) heliarc or T.I.G.

Arc welding is used on heavy sheet metals and on structural members such as angle, channel iron, and flat bar stock. The rods, called electrodes, are made of various alloys and are coated with a hard flux. They are usually some kind of mild steel or stainless steel. They are melted and formed into the weld by means of an electric current of comparably high amperage and low voltage.

Heliarc or T.I.G. (tungsten inert gas) welding is used on such metals as aluminum and stainless steel. This type of welding uses electricity, as in arc welding, plus a

shield of inert gas such as helium or argon. A tungsten tip is used instead of the regular electrode. The filler metal is then added, as in oxyacetylene welding. The filler rods are very similar to the oxyacetylene welding rods. Heliarc welding is very expensive.

In arc welding, brazing, and silver soldering, a flux is needed to remove the oxidation and prevent further oxidation while the weld or union is being made. Borax and similar chemicals are among the most commonly used fluxes in brazing and welding. After the welded or brazed joint cools, the flux forms a hard, crustlike coating similar to glass that has to be removed by chipping or brushing with a steel wire brush.

Resistance welding is commonly called **spot welding**. You may need to use this process during maintenance of equipment. Some pieces of equipment have sheet metal guards or conveyor plates that must be fastened but are too thin to be welded conventionally. Spot welding is a fast method for doing this. It is also inexpensive, easy, and very efficient under most conditions. There are several types of spot welders in use.

Portable spot welders are more practical for millwrights, because they may be taken to the assembly location or where a repair is necessary. They weigh about 22 to 42 pounds and are easy to transport. The transformer is left in a truck if there is access to the machine. Long cables are run from it to the portable welder. Some portable models spot-weld mild and stainless steel up to 3/16-inch combined thickness or two pieces of 16-gauge galvanized sheet stock.

Water-cooled spot welders are found in both pedestal models and rocker-arm models. These welders work on the principle of applying pressure to two or more pieces of metal by means of an electrode or tong on each side of the pieces. Electrical current is passed from one electrode to the other through the metal to make a bond. Pressure, weld time, and hold time are critical factors in this process and are kept in close tolerances. Water is circulated through the electrodes during use to keep the heat within limits. The two types of power mechanisms used for large spot welders are stored electricity and direct electricity. The direct source discharges the electricity

as it comes from the line. The stored source comes from a bank of capacitors and is available immediately.

Stationary spot welders can weld mild carbon steel, cold-rolled and hot-rolled steel, pickled and oiled steel, low alloy and medium carbon steel, stainless steel, and galvanized steel. Both stainless steel and galvanized steel require a longer weld time than mild steel. A slightly greater electrode pressure is needed for galvanized steel, as the zinc coating must be forced aside at the weld to permit the base steel to fuse. Electrodes must be cleaned more often when galvanized steel is being spot-welded.

The larger spot welders are operated by either a foot pedal or an electrical foot switch. Air-operated, electrically controlled models function efficiently on a minimum of 40 pounds of air pressure.

Welding Safety

Since you are working with flames, sparks, and hot metals, you must always be careful in any type of welding operation. Always use the proper goggles or mask. Use respirators on jobs where there are dangerous fumes. Wear clothes that keep welding sparks and hot metal out of your shoes. Wear hard-toed shoes when you are using a cutting torch, as metal could drop on the feet. Never touch hot metals. Do not weld in areas where flammable materials and liquids are stored.

Exercise

1. What are the three parts of oxyacetylene welding?
2. Why are oxyacetylene welding rods coated with copper?
3. What happens during the brazing process?
4. How does silver soldering compare in strength of joint?
5. What are the three general categories of electrical welding?
6. How are arc welding rods used to join metals together?
7. What other ingredient besides electricity is used in heliarc welding?
8. What is the purpose of a flux in arc welding, brazing, and silver soldering?
9. What is resistance welding commonly called?

10. Why are portable spot welders more practical to use?

11. Upon what principle do water-cooled spot welders work?

12. Why is greater electrode pressure needed to spot-weld galvanized steel?

13. How much air pressure is needed for an air-operated, electrically controlled spot welder?

G-3

Assembly, Disassembly, and Maintenance of Equipment

Objectives: After completing this assignment, you will be able to—

1. give the procedures to follow when disassembling industrial equipment;
 2. discuss the methods of transporting equipment to a new location; and
 3. give the procedures to follow when setting up industrial equipment.
-

Disassembly of Equipment

Before beginning any disassembly work, you should be sure that you have all tools and equipment necessary to do the job. When you contract a disassembly job, an inspection will let you know what tools and materials will be needed. If you have to leave a job halfway through to secure other equipment, you lose valuable time.

A disassembly job can be very complicated. It may consist of a complete breakdown of a machine, transporting it to another location, and reassembling it to its previous condition. It is possible that the machine is old and blueprints are no longer available. If this is the case, you must be sure that you can reassemble it as it was. This often means you must label parts as they are removed. You may even want to list the sequence of removal, then reverse this sequence to replace the parts during installation.

Always disconnect the utilities first. You must shut off the electricity before doing any electrical work. Also, record the voltage used, phase, or other information concerning energy needed at the new location. Be aware of any air or water pressure needed for the equipment, since those hook-ups may be needed at the new location.

Sometimes gas or oil is used as an energy source for kilns or other pieces of equipment needing heat.

Carefully remove all bolts, screws, or other fastening devices. At times you may have to cut welded pieces apart and reweld them at the new location. If there are a number of heavy parts, you may have to break the machine down to one basic block. Be sure all fasteners are out before the part is lifted or moved. The part or parts should be carefully secured to a hoist or properly blocked on other moving devices, so there is no danger of dropping or movement during a lift of transfer from its present location.

Moving the Equipment

If you have to transport the equipment some distance on a truck or railway car, be sure it is securely fastened to the moving vehicle. If the equipment is being transferred to another city, always cover it with water-resistant materials to prevent rusting.

Often machinery is moved from one location to another in the same building. You may have overhead trolleys to make this transfer. Be sure the chain hoists and trolley can handle the load requirements. Sometimes you will be able to move the equipment by carts, trucks, dollies, or

forklifts. Transport the machinery slowly and carefully. A drop of only one foot may cause a great deal of damage to delicate machinery.

Setting Up Industrial Equipment

Sometimes the equipment is not installed directly on the floor. You may have to construct a special slab, platform, or base. These procedures were outlined in Assignment G-1. Hoists, cranes, or block-and-tackle assemblies will be needed if the equipment is to be lifted onto an elevated base.

The first step during assembly is to place the equipment at the exact location desired. Secure the machine or equipment to the base or floor with screws, bolts, welds, or other fasteners. Leveling and plumbing is done at the same time you are securing the equipment. You may have to use jacks, blocks and tackles, or hoists to level the equipment.

Sometimes parts or accessories must be added to the equipment. Be sure that blueprints are checked to see if there are special installation procedures. New equipment will probably have instructions for the complete installation process. Certain parts may need to be in place before other parts are installed, since some equipment has close tolerances between specific parts.

Often electric motors must be installed after the basic machine is in place. The motor may turn a geared shaft or it may power the machine by pulleys and belts. The pulley should be tightly secured to the motor shaft and in line with the pulley on the piece of equipment. Be sure the belt has proper tension. A belt that is too tight may wear out a motor shaft or mandrel bearings. If the belt is too loose, it may slip off the pulleys or spin on them to cause a loss of power and excessive belt wear.

Often belts or other moving parts must be guarded. Install these devices, tighten them securely, then check to be sure they will not touch any moving parts once the equipment is placed into operation. If you are installing conveyors, also check the movements to see that all moving parts are free.

When all parts are in place and secure, check to see if you have missed any steps. Remove all tools or devices you have used in the assembly process.

At this point, attend to lubrication needs. If the equipment is new, lubrication may not be necessary. Wipe up any oil or grease spills before leaving the job.

Some equipment may operate on electricity only. You may hook up the electricity, although usually an electrician will connect the equipment to the electrical source. This also applies to equipment that uses natural gas, oil, air pressure, or water as a cooling agent. A plumber may install or connect these lines.

Be sure that you are on hand when the equipment is started to see that everything is in working order. During this time, it is sometimes necessary to make adjustments.

Maintenance of Equipment

Many millwrights work for one specific manufacturer. Not only are they responsible for setting up and dismantling machines and equipment, but they are also responsible for their maintenance. This usually consists of specific schedules for inspecting the machines and equipment. These inspections consist of checking for loose or worn belts, worn bearings or gears, warped axles or shafts, leaking pipes or hoses, worn electrical wiring, or erratic movement of wheels and conveyors. Millwrights sometimes listen for a whine or squeal in certain machines. Those who have been around the equipment for a long while can often recognize potential problems before serious damage occurs. Periodic lubrication schedules are also maintained by millwrights.

Of course, millwrights are on call any time there is a breakdown in a particular machine. It might be a minor problem, or it may entail a complete breakdown of the piece of equipment. When belts break, the machine has a short "downtime," but if bearings or gears are involved, hours or days may be involved. Sometimes new shafts must be turned on a metal lathe, gears must be brazed and filed, or broken parts must be welded. The millwright must always be prepared to handle any breakdown by making accurate repairs or replacements in a minimum amount of time.

Exercise

1. What should you acquire before beginning any disassembly work?

2. What may have to be done if a machine is old and blueprints are not available?
3. What should be disconnected before disassembling a machine?
4. What should be out of a machine before a part is lifted or moved?
5. What should you do if the equipment is being transferred to another city?
6. Why should chain hoists and trolleys be checked before a unit is lifted?

7. What may have to be built for the piece of equipment?
8. What is done at the same time the equipment is secured?
9. What may happen if a belt is too tight on a pulley?
10. What is your job when the equipment is started?
11. What must the maintenance millwright always be prepared to do?

H-1

Setting Up a Rigging (Millwright) Business

Objectives: After completing this assignment, you will be able to—

1. explain the forms or types of businesses that may be organized;
2. discuss the taxes and insurance the owner of a rigging business is responsible for paying and collecting;
3. explain what type of agreement or contract must be drawn up before starting a rigging job; and
4. discuss finances, personnel, and equipment needed by the owner of a rigging business.

Types of Organization

The owner of a rigging business can set up a business in several different ways. A **sole ownership** is the form used by most owners. The full responsibility for the company rests on one individual. No formal documents or agreements are necessary, and business and personal income may be the same for tax purposes.

A **partnership** agreement consists of individuals sharing responsibilities, liabilities, work, and profits. Many of these arrangements combine the millwright experience of one person with the management abilities of another. A **limited partnership** usually consists of one person supplying the capital and the other person running the business.

A **corporation** involves more legal documents, but gives tax and liability advantages. Business and personal income taxes are separated, which allows for tax advantages. If losses occur in a corporation, the owner or owners are liable for only part of those losses. Capital can also come from stockholders. An attorney should be retained to draw up the legal documents.

Taxes

The owner must obtain an employer's identification (EI) number from the Internal Revenue Service. This number is used on forms submitted with social security and federal income taxes that have been withheld from employees' salaries. In states with sales tax laws, the owner must also submit these taxes periodically. Sales tax laws vary from state to state.

The business must pay federal unemployment taxes if it has paid wages of \$1,500 or more in any calendar quarter and had one or more employees on at least some portion of one day in each of 20 or more calendar weeks. The basic tax rate is 3.2 percent of the first \$4,200 of taxable wages received by each employee. The actual rate to pay is much less because the federal government gives credit for unemployment taxes that are paid to the state government.

State unemployment taxes are usually based on the taxable wage base of a quarter. The rate of tax charged is also usually determined by the employee's unemployment experience. In some states the worker is also assessed through payroll deductions.

Some counties, towns, and cities impose other taxes. These include taxes on gross receipts of businesses and unincorporated business taxes.

Insurance

The owner of the company should carry enough insurance to protect the workers and the owner from losses.

Worker's compensation covers liability if a worker is injured on the job. Some coverages also include driving to and from installation locations or during the moving of equipment from one place to another.

Property insurance protects the rigging company property and equipment either at a central office or materials and equipment located temporarily at an assembly or disassembly location.

Some company owners furnish their workers with group insurance policies. They may pay for some or all of the employee's insurance as a fringe benefit.

Contracts

No rigging job should begin until a binding contract or agreement has been drawn up. The contract is between the rigging company and the shop or manufacturer needing the work done. The contract should include the price of the completed project, terms of payment, services, specifications, and time allowed for disassembly, assembly, and/or moving.

Financing the Business

Few rigging companies can begin a new business or buy one without acquiring additional capital. How much capital is needed depends on the type of work to be done, the equipment that must be purchased, the number of employees that will be hired, the size and staff of an office, and the amount needed for the owner's living expenses.

Large jobs call for a large outlay of money, and loans are sometimes necessary at that time. The owner of a rigging business must build a good reputation for dependability so the risk factor to the lending institution is less.

The lending institution usually asks for a complete financial statement from the owner. It may also ask for a personal

resume if it has not done business with the owner before.

The owner with sufficient capital can pay cash for materials and labor, thereby avoiding the payment of interest on borrowed money. Sometimes cash discounts are allowed on materials. With enough cash on hand, the business owner can invest in equipment to save time and money.

Office

A large company must have an office or offices to keep up with all the necessary paperwork. Smaller business owners may work out of their homes. In this case, someone must always be near the phone to handle business calls. Many owners now use the timesaving two-way radio or CB. The base unit is installed in the home or in the office. The owners or other workers in the field make contacts through the base unit. Information is then relayed to other workers, the company owner, or to businesses that are supplying materials or equipment. This way, time-consuming trips to various places do not have to be made.

Equipment and Materials

The owner of the business must spend a great deal of money on equipment to be successful. Although most workers will have some hand tools, the owner furnishes such equipment as hoists, scaffolds, cement mixers, and wheelbarrows. Some company owners have their own large trucks for hauling heavy equipment. The owner should buy or lease tools and materials from businesses that are reliable in terms of having the proper materials and tools and being able to furnish them as promised. Waiting for tools and materials can disrupt the entire operation.

Personnel

When the owner of a rigging company begins operation, it is essential that a good labor force be hired. The new owner usually has friends who are good in their work and want to get in on "the ground floor" of a new business. Workers must be carefully selected. Starting a new business with unreliable help can mean instant failure. Be sure you have enough employees. An under-

staffed office or too few workers on the job soon make scheduling impossible.

Exercise

1. What form of business is used by most rigging owners?
2. What is a limited partnership?
3. Where does an owner obtain an employer's identification number?
4. On what are state unemployment taxes usually based?
5. What does worker's compensation cover?
6. What are the advantages of the owner having sufficient capital on hand?
7. What device is used to relay information to the owner, office, or workers on the job?
8. What does an understaffed operation cause?
9. What should be done before rigging work begins?
10. Why should the owner build a good reputation for dependability?

H-2

Human Relations in a Business

Objectives: After completing this assignment, you will be able to—

1. discuss factors involved in the selection of personnel;
 2. explain how to effectively train new employees; and
 3. discuss the effects of good human relations and morale on the employee's production.
-

Selection of Personnel

You, as an owner of a business, cannot afford to hire the wrong person for a particular job. This means that hiring must be done objectively and not emotionally. Just liking the applicant is not enough. Hiring must be based on the person's experience, attitude, and abilities that match the job.

First, you must be familiar with the duties and responsibilities of the position you are filling. Most owners of rigging businesses have at one time or another been involved in every phase of jobs done by millwrights. This person usually knows the operation of all equipment and the steps to use in assembling, moving, and disassembling machines. This makes it much easier to know how a certain individual can fill a specific position. If you have a large company, it sometimes helps to have a complete job description of the job to be filled. You should stay current with all phases of the job and any changes that may occur because of new equipment purchased through the years.

When you begin looking for new workers, a number of organizations can be helpful. State employment agencies, private employment agencies, recruiting firms, unions, and various social service organizations have leads on people wanting or needing jobs. The newspaper ad is used quite

often to attract employees. Be sure to give enough information so that you do not have to interview a great many unqualified people. One of the best ways to get new employees is through your current employees. They can give you names of people who are qualified and interested in working for you. If your employees are satisfied, they will be your best advertisement in attracting new employees.

The first step in evaluating potential employees is to check their backgrounds. An application form is the best source of some of that information. You can quickly determine if the applicant's education, training, and experience qualify the person for the position. For some jobs, it may be possible to train an individual to meet the standards of the job. Other jobs may require someone with many years of experience. For example, you could hardly afford to hire an unskilled worker as a millwright. But you could use the worker to remove bolts and screws for a qualified millwright.

You should have some type of interview, whether formal or informal, with the applicant. This gives you a chance to ask important questions about particular phases of the work. The applicant may also have questions, and it is better to answer them before the person is hired. Don't expect miracles during the interview. You may get a few impressions, but since the applicant is

trying to make a good impression, it is hard to get a clear picture of the individual.

Several steps should be kept in mind during the selection process:

1. Analyze the position.
2. Determine what abilities the employee must have to fill the job.
3. Study personal factors, such as age, education, and health of the applicant.
4. Write a complete job description.
5. Interview objectively.
6. Check all references.
7. Compile and review all information before making a final selection.

Employee Training

All employees should have an orientation period. The job should be explained in full. The person may have the background experience for the particular position, but the new position may include responsibilities unique to that job. Give the employee an overview of the company policies and rules.

Some employees must go through a training period. The length of time depends on the job responsibilities. For learning to take place during the training period, the employee must have the ability to learn at the level of the training program. The employee must also have the abilities and motivation needed to accomplish the job.

The people doing the training must organize their work to enable the new employee to learn. They must be patient and support the new worker during this training period. You, as the owner, must also support the training and give the trainer ample time to bring the new employee to the proper level of proficiency.

The training program should include a great amount of safety. If employees learn safety from the beginning, they will form safety habits that will save time, expense, and suffering.

Be sure your trainers are competent. They must have the ability to communicate with others. Do not ask employees to train other people if they are opposed to the idea. They may only succeed in confusing the new worker. Ask other workers to support the training since they once had to go through it themselves. Check periodically. Let the new employee know that you are personally interested in the progress taking place. Ask

for suggestions that might make the training period easier.

Morale and Production

Good individual attitudes on the job lead to high group morale. When morale is poor, production always drops. It is very important for you to understand the viewpoints of your employees and to recognize if an individual or group problem exists. If you notice that some employees tend to pick on another individual, put a stop to this immediately. This tends to affect not only that individual, but also the company as a whole. Some employees are natural leaders. This means that they may lead other employees into bad situations as well as good. A leader who stirs up trouble can disrupt a complete project. You can head off these problems before they become a source of poor morale. A good business owner does not allow employees to "side" against groups or individuals.

Many people leave high-paying jobs because other factors cause dissatisfaction. Four primary reasons for good morale are:

1. Satisfaction in the job itself
2. Pride in co-workers
3. Acceptance of pay policies and promotion opportunities
4. A feeling of belonging to the company

High employee turnover, complaints, absenteeism, and low production are often indications of low morale. If any of these exist, immediately begin checking. Find out what is wrong before skilled workers begin leaving.

There are many ways to improve human relations. First, you can improve your understanding of human behavior. Accept the fact that others do not look at things the way you do. Respect differences of opinion. Be interested in all of your employees—not a select few. Correct poor conditions as soon as you are aware that they exist. Provide any information that affects your employees, and give them a feeling of security. Promote from within the business. Show your good workers that you recognize their extra efforts. Offer only constructive criticism—and only in private. Never criticize one employee to another employee. See that your supervisors are fair. Give only correct information. Above all, be fair.

Exercise

1. What must hiring be based on?
2. What organizations may be helpful in finding new employees for your company?
3. What is one of the best ways to get new employees?
4. What is the first step in evaluating potential employees?
5. Why is an interview important?
6. What is the last step in the selection process?
7. What should all employees have when they begin a new job?
8. What determines the length of the training period?
9. What characteristics should the trainer of new employees have?
10. Why should the trainer include safety in the training program?
11. Name the four primary factors that lead to good morale.
12. How does poor morale affect the company?
13. What are indications of low morale?

Millwright

Instructor's Guide

D.O.T. 638.281-018

By

L.A. Grimes, Jr.

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Contents

Foreword / v
Acknowledgments / vi
Notes for the Instructor / vii
Answers to Exercises / 1
Answers to Assignment Tests / 17
Assignment Tests and Work Sheet / 23

COMPLIANCE STATEMENT

TITLE VI, CIVIL RIGHTS ACT OF 1964; THE MODIFIED COURT ORDER, CIVIL ACTION 5281, FEDERAL DISTRICT COURT, EASTERN DISTRICT OF TEXAS, TYLER DIVISION

Reviews of local education agencies pertaining to compliance with Title VI Civil Rights Act of 1964 and with specific requirements of the Modified Court Order, Civil Action No. 5281, Federal District Court, Eastern District of Texas, Tyler Division are conducted periodically by staff representatives of the Texas Education Agency. These reviews cover at least the following policies and practices:

- (1) acceptance policies on student transfers from other school districts;
- (2) operation of school bus routes or runs on a non-segregated basis;
- (3) nondiscrimination in extracurricular activities and the use of school facilities;
- (4) nondiscriminatory practices in the hiring, assigning, promoting, paying, demoting, reassigning, or dismissing of faculty and staff members who work with children;
- (5) enrollment and assignment of students without discrimination on the basis of race, color, or national origin;
- (6) nondiscriminatory practices relating to the use of a student's first language; and
- (7) evidence of published procedures for hearing complaints and grievances.

In addition to conducting reviews, the Texas Education Agency staff representatives check complaints of discrimination made by a citizen or citizens residing in a school district where it is alleged discriminatory practices have occurred or are occurring.

Where a violation of Title VI of the Civil Rights Act is found, the findings are reported to the Office for Civil Rights, Department of Health, Education and Welfare.

If there is a direct violation of the Court Order in Civil Action No. 5281 that cannot be cleared through negotiation, the sanctions required by the Court Order are applied.

TITLE VII, CIVIL RIGHTS ACT OF 1964: EXECUTIVE ORDERS 11246 and 11375; TITLE IX 1973 EDUCATION AMENDMENTS: REHABILITATION ACT OF 1973 AS AMENDED; 1974 AMENDMENTS TO THE WAGE-HOUR LAW EXPANDING THE AGE DISCRIMINATION IN EMPLOYMENT ACT OF 1967; VIETNAM ERA VETERANS READJUSTMENT ASSISTANCE ACT OF 1972 AS AMENDED IN 1974.

It is the policy of the Texas Education Agency to comply fully with the nondiscrimination provisions of all federal and state laws and regulation by assuring that no person shall be excluded from consideration for recruitment, selection, appointment, training, promotion, retention, or any other personnel action, or be denied any benefits or participation in any programs of activities which it operates on the grounds of race, religion, color, national origin, sex, handicap, age, or veteran status (except where age, sex, or handicap constitute a bona fide occupational qualification necessary to proper and efficient administration). The Texas Education Agency makes positive efforts to employ and advance in employment all protected groups.

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Foreword

This publication is one of a series of individualized instructional materials for students in industrial cooperative training. Students using this material can work at their own pace, learning those things that best fit specific needs. The design of the material makes it possible to relate work experience on the job with information studied at school.

Although the material is self-paced, it should be used under the supervision of an instructor. For that reason, two basic publications are offered—a student's manual and an instructor's guide.

The **student's manual** is for the person in training. It is self-contained. Each assignment has all the information needed, a list of objectives that should be met, and exercise questions that can help in meeting those objectives.

The **instructor's guide** has additional information that may help the instructor help the student. There are suggestions on how the student should use the student's manual, and how the instructor can coordinate work experience and learning at school. The instructor's guide also contains (1) answers to both exercise questions and assignment test questions, (2) one set of assignment tests, and (3) a work sheet that the instructor can conveniently use to match related instruction to job experience for the student.

Although both publications are copyrighted, an instructor should feel free to make copies of the assignment tests and work sheet, which have been placed in a separate section of the instructor's guide, readily accessible for copying. If the instructor prefers, copies of these same sheets can be ordered separately for individual students from Extension Instruction and Materials Center, The University of Texas at Austin, P. O. Box 7218, Austin, Texas 78713.

Every effort has been made to produce a publication that addresses the unique needs of our current student population. Students with limited English proficiency (LEP) as well as handicapped, educationally disadvantaged, and nontraditional students may require modification of the material in this publication. The professional staff of EIMC will gladly work with any instructor having these students to show how the instructional material can be adapted for specific individualized instruction. Consult local, state, and federal agencies that offer assistance and guidance and that can provide sound recommendations for productive classroom management.

Kathryn R. Allen, Ph.D.
Director, Extension Instruction
and Materials Center

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Notes for the Instructor

The instructor's guide is provided to help the instructor make certain that each student gets the most benefit possible from both the student's manual and what he or she does on the job. To do so, this guide includes—

1. notes for the instructor;
2. answers to assignment exercises;
3. answers to assignment test questions;
4. the assignment tests, in the form in which they will be used by the student; and
5. a work sheet for planning and recording work experiences and related assignments from the student's manual.

These notes and all answers to exercises and test questions should be kept by the instructor. The actual assignment tests and the work sheet may be removed from this guide for use or reproduction. For convenience, this guide is punched for notebook use.

Occupational Requirements

The contents of the student's manual are related to the occupational title of millwright, D.O.T. 638.281-018, in the Dictionary of Occupational Titles (1977), published by the U. S. Department of Labor.

Assignment Design and Teaching Principles

The student's manual presents related technical information to (1) groups of trade and industrial students with diversified vocational objectives and (2) homogeneous groups in which the learning levels of individual students vary considerably. The student's manual is not intended to be used as a correspondence course. Instead, it must be used by students under the direct supervision of an instructor.

Each assignment in the student's manual is designed to use as many fundamental teaching principles as possible. For that reason, each assignment is broken down into four parts—objectives, technical information, exercise, and test.

Objectives. The first teaching principle is that the student should be informed at the outset what he or she should learn from an assignment. This is done through a list of objectives for each assignment. These are performance objectives that can be tested when the assignment is completed.

Technical Information. The second teaching principle is that technical information should be presented in a complete but concise form. All the information needed to complete the assignment exercise and meet the objectives is found in the assignment itself. This information has been organized to help the student learn more easily—either step by step, moving from simple to complex, or by logical topics and subtopics.

Exercise. The third teaching principle is that technical information is learned better if it can be applied as soon as possible after it is presented. This is done by using an exercise for each assignment. The exercise questions are phrased to emphasize key points and to aid in evaluating the technical information. The instructor should impress on students that both the objectives and the technical information should be read before they attempt to answer the questions in the

exercise. An exercise is not an open-book test, and this idea should be discouraged. Answers may be useful in helping a student who is having difficulty with an assignment exercise.

Test. The fourth major teaching principle is that the effectiveness of an assignment should be evaluated. This is made possible by brief assignment tests provided in this guide. A test should be given when an assignment is completed. Each test is based on the objectives stated for that assignment.

The answers to both assignment exercises and assignment tests have been made as brief as possible to make it easier for the instructor to check the student's classroom work quickly and accurately. All answers should be retained by the instructor for obvious reasons.

Tests and Work Sheet

The last section of this instructor's guide contains the tests and work sheet, which can be removed for reproduction or other uses. The instructor may reproduce these without the publisher's permission. Sets of the material in this section can also be ordered separately.

The work sheet is provided for the convenience of the instructor in keeping track of a student's progress.

**Answers
to
Exercises**

Exercise A-1

Using This Manual

1. technical instructions, procedures, and illustrations
2. the combination of classroom study and the actual work on the job
3.
 - (1) objectives
 - (2) information
 - (3) exercise
 - (4) test
4. before reading the information part of the assignment
5. Read the information and study the illustrations.
6. tools and materials, as well as certain procedures and operations
7. when answering the exercise questions or when certain tasks on the job make it necessary
8. to help the student meet the objectives
9. in the form of complete sentences
10. Correct any mistakes and place the papers in his or her notebook.
11. when the exercise questions have been answered correctly
12. make the student think
13. as an assignment is completed, or several tests may be combined as a weekly or six-weeks' test
14. fill-in-the-blank and multiple-choice questions

Exercise A-2

Millwright Careers

1. by referring to layout plans, drawings, and blueprints
2. an engine lathe
3. through the use of screws, bolts, rivets, and welding equipment
4. about 95,000
5. those in transportation equipment, metal, paper, lumber, and chemical products
6. 4 years
7. mathematics, mechanical drawing, and machine shop
8. about the same as for other occupations
9. about \$14.81, with an extra \$2.18 per hour in benefits
10. cuts and bruises, injury from falling objects, falls, and strains from lifting heavy equipment
11. protective equipment

Exercise A-3

Personal Safety

1. It might collapse under the additional weight, or the materials might be jarred loose.
2. dry
3. gasoline
4. (1) single-unit
(2) stepladder
(3) extension
5. transparent
6. when working near energized electrical equipment
7. one-quarter of its working length
8. You may lose your balance if you stand on the top.
9. a hard hat
10. a squatting position
11. the National Institute for Occupational Safety and Health (NIOSH)
12. where there is a possibility of an eye injury from flying particles, chips, caustic materials, and solvent splashes; also, when using lathes, grinders, drills, welders, and other power equipment

Exercise A-4

Equipment Safety

1. Forcing a dull cutting tool often causes accidents.
2. so they will not slip off a hammering surface when a blow is struck
3. because they may cause a person to lose his/her balance and fall into a moving part
4. to prevent the bit from "grabbing" the material and spinning it
5. to prevent the piece being ground from slipping between them
6. when the grinder is first started
7. a shatterproof face shield or goggles
8. so that machine parts or working materials are not thrown from the machine
9. loose apparel
10. by touching a hot bit
11. to prevent kickback
12. (1) eye damage from not wearing protective goggles or a welding hood
(2) burns from sparks or handling hot metals

Exercise B-1

Adding and Subtracting Common Fractions

1. a part of a whole
2. as $\frac{1}{4}$
3. two sixths ($\frac{2}{6}$)

4. the numerator
5. the denominator
6. finding the lowest common denominator
7. an improper fraction
8. those containing both a whole number and a proper fraction
9. the lowest number into which the denominator of each of the fractions you want to add or subtract will divide evenly
10. A whole number is borrowed and added to the smaller fraction.
11. a. $\frac{5}{12}$
b. $\frac{19}{21}$
c. $\frac{7}{8}$
d. $\frac{19}{35}$
e. $\frac{5}{18}$
12. a. $\frac{3}{8}$
b. $\frac{19}{40}$
c. $\frac{5}{12}$
d. $\frac{1}{18}$
e. $\frac{31}{63}$

Exercise B-2

Multiplying and Dividing Common Fractions

1. a number that is multiplied by another number
2. a number that is used to multiply another number
3. Multiply the numerator of the fraction by the whole number, and then divide the result by the denominator.
4. Multiply the numerator of one fraction times the numerator of the other. The denominators are also multiplied by each other.
5. the number that divides into the dividend
6. The denominator of the fraction is multiplied by the whole number.
7. turning the fraction upside down
8. a. $\frac{9}{14}$
b. $\frac{3}{40}$
c. $\frac{2}{3}$
d. $\frac{1}{10}$
9. a. 2
b. 2
c. $\frac{11}{12}$
d. $\frac{8}{9}$

Exercise B-3

Decimal Fractions and Conversions

1. as decimal fractions
2. 0.003
3. a. 30.5
b. 14.343

4. a. 7.2
b. 50.70
5. Multiply as if you were multiplying whole numbers, and mark off to the left as many decimal places in the product as you have in both the multiplier and the multiplicand.
6. a. 0.183
b. 1.2496
7. 2
8. a. 0.5
b. 0.375
c. 0.166
d. 0.6
9. a. $\frac{1}{2}$
b. $\frac{3}{4}$
c. $\frac{7}{400}$
d. $\frac{19}{400}$

Exercise B-4

Percentage, Ratio, and Proportion

1. a. $\frac{5}{100}$
b. $\frac{1}{5}$
c. $\frac{2}{5}$
2. a. 75%
b. 10%
c. 15%
3. a. 1:20
b. 1:5
4. a. 10%
b. 4%
5. a. 0.08
b. 0.87
c. 0.03
6. a. 8%
b. 17%
c. 98%
7. the statement of an equal relationship between two ratios or fractions
8. the numerator
9. Multiply the fraction by 100 and add the percent sign.

Exercise B-5

The Metric System

1. One meter is one ten-millionth of the distance from the equator to one of the poles.
2. 0.27 liter
3. 5.44 kilograms
4. 3.6 kilometers

5. 28.35 grams
6. 39.37 inches
7. 1.057 quarts
8. 18.925 liters
9. the gram
10. 255.15 grams

Exercise B-6

Reading Blueprints

-
1. Too much guesswork is involved, which is expensive and time-consuming.
 2. a foundation plan and a floor plan of the building
 3. so you will not dig up utility lines and you will know where to "hook up" the equipment being installed
 4. to see if extra support is needed for the roof when walls must be removed
 5. on the specification sheets of the blueprint
 6. the internal and external construction and movements of specific equipment
 7. how each part fits into a particular assembly
 8. symbols
 9. to check dimensions that are not shown on the blueprint
 10. eleven
 11. They are stamped on one end of the scale.

Exercise C-1

Layout and Measuring Tools

-
1. the measurement of distance on a straight line between two points
 2. It identifies the units or divisions on a measuring device.
 3. concave
 4. for laying out, measuring, and squaring small materials
 5. (1) square head
(2) center head
(3) protractor head
 6. They are more quickly and accurately set.
 7. between the anvil and the face of the spindle
 8. in laying out angle cuts that are transferred from an existing object or layout
 9. to align rivet and bolt holes in sheet metal parts
 10. a spirit level
 11. You hold it on the surface to be marked, which dislodges the chalk from the line and deposits it on the surface in a straight line.
 12. for vertical layout and checking

Exercise C-2

Handsaws

-
1. The handsaw used for rough carpentry work has coarser teeth.
 2. so they taper from the back to the toe and from the cutting edge toward the back edge of the blade
 3. the crosscut saw
 4. like small chisels
 5. at an angle of 45° to the work surface
 6. a strong, rigid adjustable steel frame with removable blades
 7. Loosen the frame tension on the blade.
 8. when every other tooth is bent to the right and the remaining teeth are bent to the left
 9. binding or pinching of the blade
 10. It should be secured in a vise or placed over sawhorses.

Exercise C-3

Files, Rasps, and Snips

-
1. a handle
 2. to enable the user to cut square shoulders, notches, or special shapes
 3. the manufacturer's name, the shape, and the cut of the file
 4. (1) length
(2) shape
(3) cut
 5. (1) bastard (coarse)
(2) second-cut (medium)
(3) smooth (fine)
 6. sharpening saws and cutting V-shaped notches
 7. by cutting a single-cut file a second time
 8. from 30 to 50 strokes a minute
 9. a file card
 10. It shatters.
 11. (1) straight-cutting style
(2) right-hand style
(3) left-hand style
 12. the one with the upper blade on the right
 13. Remove surplus material with rough cuts.
 14. File any jagged edges.

Exercise C-4

Pounding and Driving Tools

1. the 16-ounce size
2. for heavy-duty work with a star drill or a cold chisel
3. near the end of the handle
4. the cheek
5. driving nails at an angle to the edge of the face of a stud or similar structure
6. to pull out nails and to pull wood structures apart
7. (1) standard
(2) Phillips
8. the metal band or sleeve surrounding the lower portion of a wooden handle
9. a square shank
10. by pushing downward on the handle
11. a more positive drive and no marring of the screwhead
12. Immerse the tool in water, and drive the wedge further into the end of the handle.

Exercise C-5

Pliers and Wrenches

1. The jaws can be opened to a wider position for gripping larger diameters.
2. to cut various diameters of regular and electric wire
3. as either nonadjustable or adjustable
4. 150°
5. twelve
6. combination wrenches or half-and-half wrenches
7. socket wrench
8. the number of teeth or points on the ratchet
9. an adjustable wrench
10. File it so that the proper size wrench will fit.
11. They reach into confined areas.
12. the size of the wrench opening

Exercise C-6

Vises and Clamps

1. at the left front corner
2. (1) continuous-screw vise
(2) rapid-acting vise
3. a swivel machinist's vise
4. by the width of the jaws and the full opening between the jaws
5. (1) C-clamps
(2) hand-screw clamps

- (3) bar clamps
- (4) spring clamps
- 6. It has a heavy iron or steel body made in the shape of a C, with a flat pad on one clamping surface and a screw pad on the other.
- 7. with both right- and left-hand threads on the same screw
- 8. for assembling and gluing doors and large pieces of wood
- 9. Different lengths of pipe can be used to hold various widths of lumber or objects during gluing or assembly processes.
- 10. like a giant spring clothespin
- 11. jaw protectors or wood scraps
- 12. in a rack out of the worker's way

Exercise C-7

Threading Tools and Reamers

- 1. to cut threads on the inside of a hole
- 2. (1) common tap
- (2) plug tap
- (3) bottoming tap
- 3. a bottoming tap
- 4. (1) T-handle tap wrench
- (2) adjustable hand tap wrench
- 5. by using three taps
- 6. to break the chip and allow the lubricating oil to cover the cutting edges
- 7. a tap extractor
- 8. the round, adjustable split die
- 9. that it is used for cutting left-hand threads
- 10. to guide the die so that it will go on the work squarely
- 11. File or grind a chamfer on the end of the rod to be threaded.
- 12. Pipe dies have threads that taper at 3/4 inch per foot.
- 13. cuts threads on the inside of a pipe or pipe fitting
- 14. enlarge and smooth drilled holes
- 15. (1) straight
- (2) spiral (helical)
- 16. drill presses and lathes
- 17. when the reamer has not been correctly ground for the particular metal that is being reamed

Exercise D-1

Portable Electric Drills

- 1. the 3/8-inch or 1/2-inch drill
- 2. (1) precision ball bearings
- (2) oilless bronze bearings
- 3. because of the greater torque
- 4. (1) geared chuck

- (2) hex key chuck
- (3) hand-tightening chuck
- 5. a bench holder attachment or drill stand
- 6. because the hole will be larger than desired
- 7. a prick punch or awl
- 8. Do not force it.
- 9. goggles
- 10. They help absorb pressure from the tightening nut and prevent the wheel from cracking.
- 11. the friction type
- 12. (1) Blow away shavings and dust.
- (2) Wipe off oil and grease.
- (3) Secure the cord.
- (4) Store the drill in a dry, safe place.

Exercise D-2

Portable Electric Circular Saws

-
- 1. the 7 1/4-inch and 8 1/4-inch sizes
 - 2. (1) worm drive
 - (2) helical gear
 - 3. to shield the lower part of the blade
 - 4. (1) crosscut
 - (2) rip
 - (3) combination
 - (4) hollow-ground combination
 - 5. 3/8 inch
 - 6. a ripping guide
 - 7. saw binding
 - 8. the outer washer
 - 9. the motor, gears, and bearings
 - 10. by coating it lightly with oil or wax
 - 11. by cutting a piece of waste material and comparing it with a sliding T bevel or protractor

Exercise E-1

Bolts, Nuts, and Washers

-
- 1. a threaded rod that is used with a nut to fasten two parts together
 - 2. It is useful for finding the proper bolt for a certain tapped hole, for replacing a nut on a bolt, or for drilling and tapping a hole for a bolt.
 - 3. coarse and fine
 - 4. the number of threads per inch
 - 5. from the underside of the head to the end
 - 6. to prevent injury to the hand
 - 7. slotted and castellated nuts

8. the Stalock fastener
9. the split ring type

Exercise E-2

Screws, Nails, and Rivets

1. the cap screw
2. to fasten thin metal parts and sheet metal together
3. with a hammer most of the way, then turned with a screwdriver
4. (1) flat
(2) oval
(3) round
5. by a weight unit abbreviated "d" or by the gauge or diameter of the wire from which they are made
6. by hammering or peening with a rivet set and hammer or with pneumatic hammers called rivet guns
7. They have flat heads, are made of soft steel, and are usually coated with tin.
8. "blind" rivet
9. by weight per 1,000
10. spikes

Exercise F-1

Gear Systems

1. Gears give a positive drive, whereas a belt drive may creep or slip.
2. (1) They can change the direction of motion.
(2) They can increase or decrease in the speed.
(3) They can magnify or reduce the force.
3. spur gears
4. a pinion
5. a helical spur gear
6. The gears are in constant contact with one another, with less lost motion and smoother action.
7. thrust bearings
8. to save space and material
9. a bevel gear
10. one revolution
11. a worm gear
12. safety to the operator
13. in the opposite direction (counterclockwise)
14. $S_2 = S_1 \times \frac{T_1}{T_2}$
15. an idler
16. by considering it as two machines and figuring each M. A. separately
17. the product of the mechanical advantages of the several machines that make it up

Exercise F-2
Belts and Pulleys

1. a motor
2. from its triangular or V-shaped cross section
3. You would lose the benefits of the side pressure.
4. step pulleys
5. when a great deal of power is needed
6. when speed changes are needed fairly often, but the change is slight
7. by moving one side of the pulley closer to or further away from the other one
8. to prevent slippage

Exercise F-3
Bearings and Springs

1. the resistance to any force that causes motion of one surface over another
2. rolling friction
3. (1) sliding or sleeve type (plain bearings)
(2) antifrictional type (roller and ball bearings)
4. (1) reciprocal motion bearings
(2) journal bearings
(3) thrust bearings
5. revolving shafts
6. There may be friction problems.
7. to resist axial thrust or force and to limit axial movement
8. two hardened steel rings (races), a number of steel balls or rollers, and a separator
9. the roller bearing assembly
10. This means that it is under constant spring-thrust or pressure.
11. (1) flat
(2) spiral
(3) helical or coil
12. helical springs
13. a tension spring

Exercise F-4
Hydraulics

1. a hydraulic machine
2. that a pressure applied to any part of a confined fluid is transmitted to every other part with no loss and that the pressure acts with equal force on all equal areas of the confining walls

3. Liquids cannot be compressed into a smaller space, but air will "give" under enough pressure.
4. (1) The system might not be full of liquid.
(2) Air could be present in the lines or cylinders.
5. ten
6. $\frac{F_1}{F_2} = \frac{A_1}{A_2}$
7. force, in pounds, applied to the small piston
8. distance
9. work output
10. a valve
11. by letting the fluid flow back to the reservoir through a return line
12. an accumulator
13. compressed air

Exercise F-5

Block and Tackle

-
1. a pulley
 2. the weight of the object being hoisted
 3. a single fixed block
 4. The length of rope that passes through your hands is always greater than the distance the load is raised.
 5. both a double block and a single block
 6. the number of the parts of rope going to and from the movable block
 7. the strength of the rope
 8. a luff upon luff
 9. from overhead trolleys
 10. the distance the effort moves divided by the distance the resistance moves
 11. the friction that must be overcome

Exercise G-1

Foundations and Platforms

-
1. to withstand the compressive forces and vibrations that occur
 2. to pour it directly on the ground
 3. forms
 4. welded wire mesh or reinforcement rods
 5. bolts
 6. bearing walls, girders, or directly on a concrete slab
 7. utility lines
 8. with bolts, welds, or both
 9. (1) ribbed-steel type
(2) cellular-steel type

10. by bolts or welds
11. Be sure that all units are leveled and fasteners are tightened.

Exercise G-2

Welding

1. (1) welding
(2) brazing
(3) silver soldering
2. to prevent rust
3. The base metal is brought up to a heat that will bond the brass or bronze rod.
4. It is one of the strongest methods of fastening thin metal together.
5. (1) arc
(2) resistance
(3) heliarc or T.I.G.
6. They are melted and formed into the weld by means of an electric current of comparably high amperage and low voltage.
7. a shield of inert gas such as helium or argon
8. to remove the oxidation and prevent further oxidation while the weld or union is being made
9. spot welding
10. They may be taken to the assembly location or where a repair is necessary.
11. They work on the principle of applying pressure to the metal pieces by means of two electrodes. Then, electrical current is passed from one electrode to the other through the metal to make a bond.
12. to force the zinc coating aside at the weld to permit the base steel to fuse
13. 40 pounds

Exercise G-3

Assembly, Disassembly, and Maintenance of Equipment

1. all tools and equipment necessary to do the job
2. You may have to label parts as they are removed.
3. all utilities
4. all fasteners
5. Fasten it securely and cover it with water-resistant materials.
6. to see if they can handle the load requirements
7. a special slab, platform, or base
8. leveling and plumbing
9. It may wear out a motor shaft or mandrel bearings.
10. You should be on hand to see that everything is in working order and to make adjustments if they are necessary.
11. to handle any breakdown by making accurate repairs or replacements in a minimum amount of time

Exercise H-1

Setting Up a Rigging (Millwright) Business

1. sole ownership
2. One person supplies the capital, and the other person runs the business.
3. from the Internal Revenue Service
4. the taxable wage base of a quarter
5. It covers liability if a worker is injured on the job. This may include driving to and from the assembly or disassembly site.
6. The owner can pay cash for materials and not have to pay interest. Materials can be purchased with cash discounts, and timesaving equipment can be bought.
7. a two-way radio or CB
8. scheduling problems
9. Draw up a binding contract or agreement.
10. so the risk factor to the lending institution is less

Exercise H-2

Human Relations in Business

1. the person's experience, attitude, and abilities that match the job
2. state employment agencies, private employment agencies, recruiting firms, unions, and various social service organizations
3. through current employees
4. Check their backgrounds.
5. This gives both you and the applicant a chance to ask and answer questions about the job.
6. Compile and review all information.
7. an orientation period
8. the job responsibilities
9. competence, patience, organization, ability to communicate, and desire to support the trainee
10. so employees will form safety habits that will save time, expense, and suffering
11.
 - (1) satisfaction in the job itself
 - (2) pride in co-workers
 - (3) acceptance of pay policies and promotion opportunities
 - (4) a feeling of belonging to the company
12. Production drops.
13. high employee turnover, complaints, absenteeism, and low production

**Answers
to
Assignment Tests**

Test A-1**Using This Manual**

1. student's manual
2. objectives
3. exercise
4. objectives
5. c. multiple-choice

Test A-2**Millwright Careers**

1. lathe
2. 95,000
3. four (4)
4. welding
5. Protective

Test A-3**Personal Safety**

1. Gasoline
2. transparent
3. Metal
4. squatting
5. hard

Test A-4**Equipment Safety**

1. dull
2. grabbing
3. Loose
4. kickback

Test B-1**Adding and Subtracting Common Fractions**

1. two
2. numerator
3. improper
4. Mixed
5. a. 19/35
b. 5/18
6. a. 5/8
b. 19/40

Test B-2**Multiplying and Dividing Common Fractions**

1. multiplicand
2. c. divisor
3. invert
4. a. 8/21
b. 2/15
5. a. 1 3/4
b. 2

Test B-3**Decimal Fractions and Conversions**

1. 0.02
2. 10.7
3. a. 0.166
b. 0.6
4. a. 3/4
b. 19/400
5. metric

Test B-4**Percentage, Ratio, and Proportion**

1. a. 2/5
b. 5/100 (1/20)
2. a. 4%
b. 10%
3. a. 0.03
b. 0.87
4. equal

Test B-5**The Metric System**

1. grams
2. liter
3. quarts
4. gram
5. 39.37

Test B-6**Reading Blueprints**

1. Framing
2. specification
3. Symbols
4. dimensions
5. 11 (eleven)

Test C-1**Layout and Measuring Tools**

1. straight
2. center
3. anvil
4. spirit
5. vertical

Test C-2**Handsaws**

1. across
2. chisels
3. set
4. frame

Test C-3**Files, Rasps, and Snips**

1. handle
2. shape
3. card
4. upper
5. surplus

Test C-4**Pounding and Driving Tools**

1. 16
2. Toenailing
3. Phillips
4. ferrule
5. wedge

Test C-5**Pliers and Wrenches**

1. Diagonal
2. Twelve
3. socket
4. opening

Test C-6**Vises and Clamps**

1. machinist's
2. rapid
3. hand-screw
4. clothespin
5. protectors

Test C-7**Threading Tools and Reamers**

1. tap
2. blind
3. extractor
4. split
5. enlarge
6. straight

Test D-1**Portable Electric Drills**

1. bronze
2. geared
3. Dull / warped
4. friction

Test D-2**Portable Electric Circular Saws**

1. 7 1/4
2. telescoping
3. 3/8
4. clutch

Test E-1**Bolts, Nuts, and Washers**

1. nut
2. fine
3. chamfered
4. split ring

Test E-2**Screws, Nails, and Rivets**

1. cap
2. oval
3. "d"
4. spikes
5. 1,000

Test F-1**Gear Systems**

1. positive
2. pinion
3. helical
4. bevel
5. idler

Test F-2**Belts and Pulleys**

1. motor
2. small
3. Variable-pitch
4. slippage

Test F-3**Bearings and Springs**

1. Rolling
2. revolving
3. Thrust
4. separator
5. lengthens

Test F-4**Hydraulics**

1. hydraulic
2. liquid
3. distance
4. output
5. air

Test F-5**Block and Tackle**

1. fixed
2. double
3. rope
4. trolleys
5. Friction

Test G-1**Foundations and Platforms**

1. compressive
2. Forms
3. girders
4. cellular

Test G-2**Welding**

1. copper
2. inert
3. spot
4. electrode

Test G-3**Assembly, Disassembly, and
Maintenance of Equipment**

1. label
2. fasteners
3. bearings
4. Leveling
5. started

Test H-1**Setting Up a Rigging (Millwright)
Business**

1. Sole
2. limited
3. quarter
4. scheduling
5. binding

Test H-2**Human Relations in a Business**

1. backgrounds
2. review
3. orientation
4. responsibilities
5. Production

**Assignment Tests
and Work Sheet**

for

Millwright

For Your Convenience

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- Instructors who do not want to reproduce the material can purchase separate sets of this section from the Extension Instruction and Materials Center, The University of Texas at Austin, P.O. Box 7218, Austin, Texas 78713.
- Each assignment test is based on a specific assignment.
- The work sheet is provided for use as a weekly log. The sheet lists the contents of the student's manual to use in coordinating assignments with work experiences.

Test A-1
Using This Manual

1. A _____ is designed to present technical instructions, procedures, and illustrations to the student.
2. The assignment _____ should be studied before reading the information part of the assignment.
3. All assignment _____ answers should be written in the form of complete sentences.
4. It is assumed that the assignment _____ have been met when the exercise questions have been answered correctly.
5. Assignment test questions in this manual are either fill-in-the-blank or—
 - a. true-false.
 - b. matching.
 - c. multiple-choice.
 - d. essay.

Test A-2

Millwright Careers

-
1. Millwrights may use an engine _____ to grind, file, and turn machine parts to dimensional specifications.
 2. There are about _____ millwrights in the United States.
 3. The apprenticeship program for millwrights is _____ years in length.
 4. Millwrights use screws, bolts, rivets, and _____ equipment to fasten and secure equipment.
 5. _____ equipment has helped to reduce many injuries to millwrights.

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Test A-3
Personal Safety

1. _____ should never be used as a cleaning agent.
2. A _____ coating should be used on wood ladders.
3. _____ ladders should never be used when working near energized electrical equipment.
4. Assume a _____ position when making a heavy lift.
5. Always wear a _____ hat to protect the head from falling objects.

Test A-4
Equipment Safety

1. Forcing a _____ tool often causes accidents.
2. Clamp materials to a drill press table to prevent the bit from _____ them.
3. _____ wearing apparel can be dangerous around revolving equipment.
4. Hold a portable circular saw straight when making a cut to prevent _____.

Test B-1

Adding and Subtracting Common Fractions

1. The fraction $\frac{1}{3}$ contains _____ sixths.
2. The number above the horizontal line in a fraction is called the _____.
3. An _____ fraction has a numerator that is larger than the denominator.
4. _____ numbers are those that contain both a whole number and a proper fraction.
5. Work the following problems in addition of fractions.
 - a. $\frac{2}{5} + \frac{1}{7} =$ _____.
 - b. $\frac{1}{9} + \frac{1}{6} =$ _____.
6. Work the following problems in subtraction of fractions.
 - a. $\frac{3}{4} - \frac{1}{8} =$ _____.
 - b. $\frac{7}{8} - \frac{2}{5} =$ _____.

Test B-2

Multiplying and Dividing Common Fractions

1. A number that is multiplied by another number is a _____.
2. The number that divides into the dividend is the—
 - a. quotient.
 - b. multiplier.
 - c. divisor.
 - d. product.
3. To turn a fraction upside down means to _____ it.
4. Work the following problems in multiplication of fractions.
 - a. $\frac{3}{7} \times \frac{8}{9} = \underline{\hspace{2cm}}$.
 - b. $\frac{1}{5} \times \frac{2}{3} = \underline{\hspace{2cm}}$.
5. Work the following problems in division of fractions.
 - a. $3\frac{1}{2} \div 2 = \underline{\hspace{2cm}}$.
 - b. $\frac{1}{2} \div \frac{1}{4} = \underline{\hspace{2cm}}$.

Test B-3

Decimal Fractions and Conversions

1. The decimal fraction for two-hundredths is _____.
2. The decimal fraction 2.5 added to 8.2 equals _____.
3. Convert the following fractions to decimals.
 - a. $1/6 =$ _____.
 - b. $3/5 =$ _____.
4. Convert the following decimals to fractions.
 - a. $0.75 =$ _____.
 - b. $0.0475 =$ _____.
5. Fractional quantities in the _____ system are always expressed as decimal fractions.

Percentage, Ratio, and Proportion

- MILL WRIGHT

Test B-5

The Metric System

1. One ounce contains 28.35 _____.
2. The unit of capacity in the metric system is the _____.
3. There are 1.057 _____ in a liter.
4. The unit of weight in the metric system is the _____.
5. There are _____ inches in a meter.

Test B-6
Reading Blueprints

1. _____ plans might be important to see if extra support is needed for the roof when walls are removed.
2. Types and sizes of pipes are found on the _____ sheets of a blueprint.
3. _____ are used to identify parts and materials on scaled-down blueprints and floor plans.
4. An architect's scale is used to check _____ that are not shown on a blueprint.
5. An architect's scale contains _____ scales.

Test C-1

Layout and Measuring Tools

-
1. Linear measurement is the measurement of distance on a _____ line between two points.
 2. A combination square has a square head, _____ head, and protractor head.
 3. Measurements taken on a micrometer are between the _____ and the face of the spindle.
 4. A carpenter's level is sometimes called a _____ level.
 5. A plumb bob is used for _____ layout and checking.

Test C-2

Handsaws

-
1. The crosscut saw is designed to cut _____ the grain.
 2. Ripsaw teeth are shaped like small _____.
 3. The _____ on a saw prevents binding or pinching of the blade.
 4. After using a hacksaw, loosen the _____ tension on the blade.

Test C-3

Files, Rasps, and Snips

-
1. Always use a _____ on the tang of a file or rasp.
 2. When buying a file, you must designate the length, _____, and cut.
 3. A file _____ is used to clean a file.
 4. Aviation snips having the _____ blade on the right are used to cut right-hand curves.
 5. Before using snips to cut to the line, always remove _____ material with rough cuts.

Test C-4

Pounding and Driving Tools

-
1. The most popular curved-claw hammer weighs _____ ounces.
 2. _____ is when you drive nails at an angle to the edge of the face of a stud or similar structure.
 3. The two main groups of screwdrivers are standard and _____.
 4. The _____ of a screwdriver is a metal band or sleeve surrounding the lower portion of a wooden handle.
 5. When a hammer handle has dried out and becomes loose, immerse the tool in water, and drive the _____ further into the end of the handle.

Test C-5

Pliers and Wrenches

-
1. _____ pliers are used to cut various diameters of regular and electric wire.
 2. _____ points or notches are usually found inside a box wrench.
 3. The _____ wrench is the fastest and easiest type of wrench to use.
 4. The length of open-end wrenches usually depends on the size of the wrench _____.

Test C-6

Vises and Clamps

-
1. A swivel _____ vise may be swiveled to various positions.
 2. Woodworking vises are either continuous-screw or _____-acting.
 3. Adjusting screws on a _____ clamp are threaded with both right- and left-hand threads on the same screw.
 4. A spring clamp looks like a giant spring _____.
 5. Jaw _____ should be used between vise jaws and the work.

Test C-7

Threading Tools and Reamers

1. A _____ cuts threads on the inside of a hole.
2. A bottoming tap is used for _____ holes.
3. A tap _____ is used to remove a broken tap.
4. The most commonly used die is the round, adjustable _____ type.
5. Reamers _____ and smooth drilled holes.
6. Flutes on reamers are either _____ or spiral (helical).

Test D-1

Portable Electric Drills

-
1. Antifriction bearings used in portable drills are either precision ball bearings or oilless _____ bearings.
 2. Drill chucks are the _____, hex key, or hand-tightening type.
 3. _____ or _____ drill bits cause drilled holes to be larger than desired.
 4. A _____ type screwdriver attachment is recommended for light finish work.

Test D-2

Portable Electric Circular Saws

-
1. The most popular portable circular saws in industry are the _____ inch and the 8 1/4 inch.
 2. A _____ safety guard shields the lower part of the portable circular saw blade.
 3. About _____ inch of the saw blade should protrude through the material being sawed.
 4. A _____ arrangement protects the motor, gears, and bearings.

Test E-1

Bolts, Nuts, and Washers

-
1. A bolt is a threaded rod that is used with a _____ to fasten two parts together.
 2. The two principal series of a bolt thread form are coarse and _____.
 3. The corners on square or hexagon nuts are usually _____ to prevent injury to the hand.
 4. The most common type of lock washer is the _____ type.

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Test E-2

Screws, Nails, and Rivets

1. The _____ screw is the largest screw for fastening two pieces of metal together.
2. Standard types of wood screw heads are flat, _____, or round.
3. Nails may be sized by a weight unit abbreviated with a _____.
4. Nails larger than 20d are called a _____.
5. Rivets are gauged by weight per _____.

Test F-1
Gear Systems

1. The advantage of gears over belts is to _____ drive.
2. Where there are two gears of different sizes meshed together, the smaller gear is called a _____.
3. A _____ spur gear has teeth that are cut slantwise across the edge of the gear.
4. A _____ gear is used when shafts are not parallel.
5. If two external gears must rotate in the same direction, an _____ must be placed between the driver and the driven gear.

MILLWRIGHT

Test F-2

Belts and Pulleys

-
1. Belts and pulleys most often transmit power from a _____.
 2. Step pulleys are sometimes used on _____ equipment.
 3. _____ pulleys are used when speed changes are needed fairly often, but the change is slight.
 4. Oil and grease should be kept off all belts to prevent _____.

Test F-3

Bearings and Springs

-
1. _____ friction is always less than sliding friction.
 2. Journal bearings guide and support _____ shafts.
 3. _____ bearings are installed to resist axial thrust or force and to limit axial movement.
 4. A typical antifrictional bearing has two hardened steel rings (races), a number of steel balls or rollers, and a _____.
 5. A tension spring _____ in action.

Test F-4

Hydraulics

-
1. A _____ machine transmits forces by means of a liquid.
 2. A hydraulic system will not work properly if it is not full of _____ or when air is present in the lines or cylinders.
 3. You must sacrifice _____ when you are trying to get a 10-pound force from a one-pound effort.
 4. Work input equals work _____.
 5. Compressed _____ is used to force fluid on top of a piston in an accumulator.

Test F-5

Block and Tackle

1. A single _____ block does not add force or speed.
2. Both a _____ block and a single block are found on a luff tackle.
3. The strength of the _____ is the limiting factor in any tackle.
4. Hoists are often suspended from overhead _____.
5. _____ may cause the actual mechanical advantage of a chain hoist to be less than that indicated by theoretical figures.

Test G-1

Foundations and Platforms

-
1. Thick concrete slabs are sometimes poured to withstand the _____ forces and vibrations that occur.
 2. _____ are constructed to hold a concrete slab in place until it has dried.
 3. Steel or wood joists are supported on bearing walls, _____, or directly on a concrete slab.
 4. Steel decking may be of the ribbed-steel or _____-steel type.

Test G-2

Welding

-
1. Oxyacetylene welding rods are coated with _____ to prevent rust.
 2. Electricity plus a shield of _____ gas is used in heliarc welding.
 3. Resistance welding is commonly called _____ welding.
 4. During spot welding, electricity passes from one _____ to another through the metal to make a bond.

Test G-3

Assembly, Disassembly, and Maintenance of Equipment

-
1. If a machine is old and blueprints are not available, you may have to _____ parts as they are removed.
 2. All _____ should be out of a machine before it is lifted or moved.
 3. If a belt is too tight on a pulley, it may wear out a motor shaft or mandrel _____.
 4. _____ and plumbing is done at the same time the equipment is secured.
 5. You should be on hand when the equipment is _____.

Test H-1

Setting Up a Rigging (Millwright) Business

-
1. _____ ownership is the form of business used by most rigging businesses.
 2. One person supplies the capital and another runs the business in a _____ partnership.
 3. State unemployment taxes are usually based on the taxable wage base of a _____.
 4. An understaffed operation causes _____ problems.
 5. A _____ contract or agreement should be drawn up before rigging work begins.

MILLWRIGHT

Test H-2

Human Relations in a Business

-
1. Owners of a business can evaluate potential employees by checking their _____.
 2. The last step in the selection process is to compile and _____ all information.
 3. All new employees should have an _____ period.
 4. The length of the training period depends on the job _____.
 5. _____ drops when there is poor morale.

- A-1: Using This Manual
- A-2: Millwright Careers
- A-3: Personal Safety
- A-4: Equipment Safety

- B-1: Adding and Subtracting Common Fractions
- B-2: Multiplying and Dividing Common Fractions
- B-3: Decimal Fractions and Conversions
- B-4: Percentage, Ratio, and Proportion
- B-5: The Metric System
- B-6: Reading Blueprints

- C-1: Layout and Measuring Tools
- C-2: Handsaws
- C-3: Files, Rasps, and Snips
- C-4: Pounding and Driving Tools
- C-5: Pliers and Wrenches
- C-6: Vises and Clamps
- C-7: Threading Tools and Reamers

D-2: Portable Electric Circular Saws

E-1: Bolts, Nuts, and Washers
E-2: Screws, Nails, and Rivets

- F-1: Gear Systems
- F-2: Belts and Pulleys
- F-3: Bearings and Springs
- F-4: Hydraulics
- F-5: Block and Tackle

G-1: Foundations and Platforms
G-2: Welding
G-3: Assembly, Disassembly, and Maintenance of Equipment

H-1: Setting Up a Rigging (Millwright) Business

H-2: Human Relations in a Business

This form is for your convenience in planning and keeping records of training. Contents of the student's manual are at the left. The columns below provide space for listing job experiences for the individual student and assignment numbers and other references related to each job. Blanks are large and divided by days so the teacher and student can list other information that might be useful in a weekly log.

Training Station

199